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HEMISPHERIC SPECIALIZATION USING A NONSENSE SHAPE FORMBOARD TASK

by

© Gordon Bradley Tanne

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Hemispheric Specialization Using a Nonsense Shape Formboard Task submitted by Gordon Bradley Tanne in partial fulfilment of the requirements for the degree of Master of Science in Psychology.

I wish to dedicate this thesis to the memory of my Mother and Father.

ABSTRACT

The split-brain model defines the right hemisphere as specialized for spatial processing and the left for verbal processing (Gazzaniga, 1970). Research demonstration of the model for spatial-tactual processing in normal human subjects has, until recently, been unsuccessful. However, Witelson (1974), using a classical dichaptic research paradigm and nonsense shapes, was able to demonstrate right hemisphere superiority of processing for the spatial-tactual modality.

The present study of normal human subjects, unlike the classical hemispheric research paradigms, used Witelson's nonsense shapes in a Sequin-Goddard Formboard-type task. Specifically, while blindfolded, one group (Preferred) used only their right hand to place the nonsense shapes into the formboard (1st Hand), then only their left hand (2nd Hand), and then both hands (Both Hands). The other group (Nonpreferred) used only their left hand (1st Hand), then right hand (2nd Hand), and finally both hands (Both Hands) to place the nonsense shapes into the formboard. Both groups then drew (Memory) and located (Location) all the shapes they could remember, first while blindfolded (Blindfold Location and Memory), and then visually (Visual Location and Memory).

The overall results (N=40) indicated that the

Nonpreferred group performed better than the Preferred group, but significantly so only for the Blindfold Location means. However, analyses also revealed a main effect for Sex which was confounded by Age. When the older females were removed from subsequent analyses (N=27) it was found that the differences between the two groups were more pronounced, with the Nonpreferred group performance being significantly better than the Preferred group for the Blindfold Location and Memory measures.

Results are primarily discussed in terms of the split-brain model and degradation hypothesis (Filbey and Gazzaniga, 1969; Rizzolatti, Umilta, and Berlucchi, 1971). However, the model and hypothesis do not adequately account for the obtained sex and age differences, the effects of vision on a haptically learned task, the nonsignificant differences between the groups for the latency trials, and the role verbal processes play in a nonverbal task. The results are discussed in terms of not only the split-brain model and degradation hypothesis, but also in terms of homologous processing areas of the two hemispheres (Rizzolatti, et al., 1971; Witelson, 1974, 1976; Gardner, English, Flannery, Hartnett, McCormick, and Wilhelmy, 1977), and a Preprocessing Model, that takes into account the fact that the two cerbral halves are dynamic intra- and interdependent hemispheres that are neither competitive nor fully co-operatuve (Marshall, 1973).

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INTRODUCTION

If one accepts (as a brain model) that for most right-handed adults the hemisphere ipsilateral to the preferred hand is the hemisphere for spatial-tactual encoding and the one contralateral to the preferred hand is for verbal encoding (Mountcastle, 1962; Weinstein, 1962; Gazzaniga, Bogen and Sperry, 1963; Bogen and Gazzaniga, 1965; Sperry, 1967; Sperry, Gazzaniga, and Bogen, 1969; Subirana, 1969; Gazzaniga, 1970; Milner, 1974a), then spatial-tactual information received by the preferred hand must travel to the contralateral hemisphere then through and out of it to the ipsilateral hemisphere for spatial-tactual encoding. Following this, the information would have to travel back to the contralateral hemisphere if any verbal encoding or output, e. g. name, verbal identification, description, is required.

Experimental research of hemispheric specialization in normal human subjects has been conducted within three classes of research paradigms: reaction time (RT), simultaneous or dichotic[1], and unilateral accuracy studies (Broadbent, 1974). The Reaction Time, Dichotic, and Unilateral paradigms have been most successfully and extensively used in testing for laterality in the visual and auditory modalities (for reviews see: Kimura, 1967; White, 1969; Gazzaniga, 1970; Berlucchi, Heron, Hyman, Rizzolatti, and Umilta, 1971; Milner, 1971; Dimond, 1972; Broadbent,

1974; Teuber, 1974; and Kammerer, 1975). The comparative lack of somesthetic research for hemispheric differences is particularly surprising in that in the split-brain research this modality has produced some of the most dramatic findings. For example, split-brain subjects could easily identify familiar (Gazzaniga, 1970) and unfamiliar (Milner, 1971; Milner and Taylor, 1972) objects and shapes using their left hand, but found the same task impossible using their right hands. These results of human split-brain research have led to the conclusion that the right hemisphere is specialized for spatial-tactual processing, and is, at the very least, the hemisphere that predominantly processes spatial-tactual information (Gazzaniga, 1970). Demonstration of this asymmetry in normal human subjects has often yielded conflicting results.

A major problem here has been in directing stimulations unilaterally from the periphery to the cortex. In the tactual modality, stimuli appear to have direct neural paths to both hemispheres (Witelson, 1974). However, the bilateral representation does not appear to be equal; with the contralateral hemisphere having a stronger representation than the ipsilateral hemisphere. And as one goes up the phylogenetic tree and away from an organism's midline direct bilateral representation seems to diminish (Brinkman and Kuypers, 1972).

A major factor of bilateral representation appears to

be the extent or degree of fine or gross motor involvement in spatial exploration of tactile stimuli. Because fine motor movement of the extremities does not appear to be processed ipsilaterally, whereas gross movement does (Brinkman and Kuypers, 1972), Witelson (1974) believes that any experiment using gross muscle movement must be interpreted in terms of interacting and interdependent hemispheres, rather than one hemisphere against the other. For example: an experiment that allows for finger-tip exploration of an object and whole arm movements would involve direct ipsilateral transmission of information and therefore active processing by that hemisphere which would affect the output. An experiment in which finger-tip exploration and only movement by the fingers allowed, however, should involve only direct contralateral transmission of information.

Based on research by Sperry, Gazzaniga, and Bogen (1969), Witelson (1974) hypothesizes that when tactual stimulation involves simultaneous and dichhaptic stimulation of the two hands, with only movement of the fingers allowed, input is direct to the contralateral hemisphere for each hand. When using the nonpreferred hand in such a spatial-tactual task the stimulus information is direct to the spatial-tactual hemisphere in the sense that sensations travel only to the contralateral hemisphere for encoding.

When the same spatial-tactual task is performed simultaneously with the preferred hand, the sensation input is also direct and contralateral, but to the verbal hemisphere. The simultaneous stimulation is believed to prevent interhemispheric communication and processing of information (Kimura, 1967).[2]

Witelson designed an experiment using unfamiliar shapes to test this hypothesis. The unfamiliar shapes were designed so that verbal labels presumably could not be used. In addition, subjects did not see the shapes, and only used the tips of their third and index fingers to feel the blocks. Whole hand or arm movement was not allowed and the shapes were presented simultaneously and directly under the two fingers of each hand. The recognition condition of the experiment was also nonverbal, requiring the subject to point out the shapes used in the learning condition from an array consisting of the test shapes as well as four other new unfamiliar nonsense shapes. Those felt simultaneously and dichhaptically with the left (nonpreferred) hand were chosen significantly more correctly than those felt with the right (preferred) hand.

It should be noted that Witelson did not entirely eliminate muscle movement in her experiment, although it was reduced drastically. She based her stimulation presentation procedure upon the research findings of Brinkman and Kuypers (1972), which was done on nonhuman primates, and has not, to

this author's knowledge, been done on human subjects. Thus the question of the differential significance in normal human subjects of gross versus fine - or for that matter any - motor movement in specifying hemispheric differences for spatial-tactual tasks still remains. More importantly, it appears that it is the hand being used and the hemisphere that sensation information goes into directly that is important.

Witelson (1974) attributes her successful demonstration of hemispheric asymmetry for the spatial-tactual modality in normal human subjects to the use of the dichhaptic paradigm of "... simultaneous but different input to the left and right hands" (page 13). In particular, she states:

> "The dichotomous stimulation in the present study may serve to highlight hemispheric asymmetry by making verbal mediation impossible, by presenting a complex task, or possibly by simultaneously activating homologous cortical areas and thus hindering interhemispheric transmission which would be of greater significance for the hemisphere less competent for the task" (page 13).

Perhaps of equal importance, Witelson was able to demonstrate hemispheric asymmetry for spatial-tactual discriminations in normal human subjects using a task that was cognitive in nature rather than a measure of sensitivity (Kammerer, 1975). Further, the experimental paradigm and

design using the nonsense shapes has been successfully replicated (Witelson, 1976; Gardner, English, Flannery, Hartnett, McCormick, and Wilhelmy, 1977) and utilized to demonstrate what is thought to be a spatial-tactual homologous area in the non-specialized hemisphere (Gardner, et al., 1977).

In a much earlier study, Halstead (1947) used the Sequin-Goddard Formboard task, as part of his neuropsychological test battery, to test for localization of function in brain-damaged subjects. He found that the task loaded on factors which affect manipulation and spatial judgements, and concluded that the task appears to be non-verbal and tends to be a more sensitive measure of brain damage to the right rather than left hemisphere. Further, although Semmes, Weinstein, Ghent, and Teuber (1960) found the same task to be sensitive to brain lesions in many parts of the brain, it was particularly so for those involving lesions to the parietal, posterior parietal, and right tempero-parietal areas. These results would appear to indicate that the task which is basically tactual, at least in the latency trials, is processed by the spatial hemisphere.

The Sequin-Goddard Formboard uses ten familiar shapes. The specific shapes are: star, cross, square, rectangle, circle, diamond, half-moon, elongated hexagon, track-shape, and triangle. In the latency trials blindfolded subjects put

the ten shapes into spaces on the board as quickly as they can. Subjects first use their preferred hand (1st Hand trial), then their nonpreferred hand (2nd Hand trial), and then both hands (Both Hands trial). Subjects are subsequently required to draw all the shapes they can recall and show where they were located on the formboard. The latter are the Memory and Location trials. The latency trials, whose dependent measure is time in seconds, allows and requires only tactual exploration of the blocks, spaces on the board, and the board itself. The dependent measures for the Memory and Location conditions are the number of shapes recalled and located correctly. The latter appear to be measures of incidental memory (Halstead, 1947).

In regard to Sequin-Goddard Formboard performance, Reitan (1960) hypothesized that if the Formboard Task is nonverbal and processed in the right hemisphere then right hemisphere brain-damaged subjects should not perform the task as well as dysphasic subjects, who in turn will not do as well as normal subjects. He found that the normal subjects did significantly better than the brain-damaged and dysphasic subjects on all measures and, contrary to his hypothesis, that the dysfunctioning subjects did significantly poorer for the latency measures than the brain-damaged subjects. However, an interesting result that appears to have been overlooked by Reitan and several subsequent researchers (e.g. Knights and Olver, 1967;

Knights, Hyman, and Atkinson, 1967; Koestline, Dent, and Giambra, 1972) was the fact that the brain-damaged and dysphasic subjects were insignificantly different from one another for the Memory and Location measures. Further, the dysphasic subjects tended to perform better on the Location measure; this, vis-a-vis the split-brain model, appears to be a spatial task and therefore should be more sensitive to neurological damage to the right hemisphere.

In a study related to the question of verbal versus spatial processing, Milner and Taylor (1972) used subjects who had undergone commissurotomy, and tested them for hemispheric specialization in a tactual task using unfamiliar shapes made of wire. They found that when information was directed to the right cerebral hemisphere (through the left hand) performance was far superior to the condition where information was directed to the left cerebral hemisphere (through the right hand). They hypothesized that their task was a nonverbal learning task and that in normal subjects

> "... the left hemisphere normally participates in tasks of this kind, perhaps by adding some identifiable and memorable verbal tag to the now accurately perceived pattern. [And that] it is clear that the right hemisphere plays the major role" (page 13).

One important point of the Milner and Taylor hypothesis

is that the "identifiable and memorable verbal tag" is added after the pattern is accurately perceived (Taylor, personal communication, February 10, 1978). Thus, it is likely in normal, dysphasic, and brain-damaged humans that spatial-tactual information transmitted from the preferred hand may be processed verbally first by the left hemisphere and then transmitted across the commissures to match up with the information being spatially-tactually processed by the right hemisphere.

An enigma of transmitting spatial-tactual information via the preferred hand may be that in transmitting this information through the verbal hemisphere to the spatial-tactual one, it may also transmit information to the verbal processing areas of the contralateral hemisphere. The verbal side may have no way of realistically encoding 'raw' tactual or kinesthetic sensation without 'advice' from the spatial-tactual side. The result may be that information received directly from the contralateral hand also gets encoded by the verbal side in the form of an ill-defined code that does not match up with the encoding done by the spatial side.[3] An alternative hypothesis, in terms of homologous processing areas (Rizzolatti, Umilta, and Berlucchi, 1971; Witelson, 1974; 1976; 1977; Gardner, et al., 1977 Smith, Chu, and Edmonston, 1977), would state that both sides process spatial-tactual information, but the right hemisphere would do so more efficiently and precisely. Therefore, for either

hypothesis, the left and right hemispheres may have two codes for the same information, neither of which match the other, or do so with a loss of efficiency or effectiveness.

Improper coding and processing may not affect the normal individual to excess, for he can effectively ignore, or override the miscoded information and inhibit it's output. However, for the brain-damaged or dysfunctioning subject, the ability to inhibit or override old information or even allow for new and proper information, may be reduced or totally impaired. Because of this, an improper output and response may occur that may not be related functionally to the spatial-tactual hemisphere, but instead may be a dysfunction of the verbal hemisphere.

The above hypotheses relating to brain functioning and processing might account for the discrepancy in interpretations made by Halstead (1947) and Reitan (1959,1960). Further to this, if the dysphasic subjects of Reitan (1960) had been tested using the nonpreferred hand first, performance may have been significantly better in relation to the nondysphasic subjects. One might expect better performance because information would be relayed directly to the spatial-tactual hemisphere and then ipsilaterally to the verbal hemisphere. At this juncture information is not only directly connected to the ipsilateral side, and perhaps spatial-tactual homologous areas, but is also directly relayed to those ipsilateral

structures responsible for processing verbal information. Unlike the case for brain-damaged subjects, dual processing in dysphasic subjects may have far reaching effects.

Dysphasics, unlike brain-damaged people, appear to have a full compliment of neural tissue that is not damaged but simply dysfunctions. Dysfunctioning tissue does not act in isolation however, rather it interacts with surrounding neural tissue and possibly even produces effects in the opposite hemisphere. Therefore, with dual processing in the two hemispheres - for example a TOTE system (Pribram, 1971) of checks and matchings - spatial-tactual information coded in the verbal hemisphere is required to be 'matched up' with the same information coded in the spatial-tactual hemisphere. The effect of this may be that certain tasks are difficult, if not impossible, for dysphasics to perform. The dysfunctioning neural tissue may not only encode inefficiently but, more importantly, incorrectly, and therefore not reliably 'match up' with the 'proper' coding of the spatial-tactual hemisphere.

Yeudall and Tanne (Ref. Note 1) attempted to experimentally verify that a direct, degradation, and dual processing hypothesis could be applied to normal human subjects using familiar shapes - specifically the Sequin-Goddard Formboard Task. They hypothesized that by using the nonpreferred hand first (Nonpreferred group) rather than the preferred hand (Preferred group), the structural

organization of the brain would be utilized more efficiently and effectively as reflected in better overall performance as measured by latency, Location, and Memory scores. The results obtained from the experiment showed that the Nonpreferred group performed better for all the latency trials and for the Memory score, but only significantly so for the Location score ($p<.05$).

Knights and Olver (1967), in comparing their subjects who had seen the blocks and were given verbal labels for each of them to another experimental group (Knights, et al., 1967) that did not see the blocks but were also given verbal labels, found that the groups that saw the blocks did significantly better than those that did not see them. The authors interpreted these results as indicating "... the importance of the relationship between visual and verbal processes" (page 246). A related qualitative observation originating in the unpublished study of Yeudall and Tanne reports that several subjects in talking about the task after completion tended to indicate the correct positions for blocks unconsciously with gestures, even when they had originally been in error in locating the shapes in the Location condition of the task. This behavior suggested that a task learned tactually, with no visual mediation allowed, could then be remembered better if the recall condition was also carried out without vision.

To test this hypothesis Tanne and Yeudall (Ref. Note 2)

designed an experiment in which subjects performed Location and Memory tasks first blindfolded and then in the standardized fashion where vision was allowed (Halstead, 1947). The Blindfold Location and Blindfold Memory tasks required subjects, after completing the latency trials, to draw on individual sheets of paper each of the shapes and then place them on a plain board where they thought they were located while still blindfolded. The results obtained showed that the Nonpreferred Blindfold Location mean was significantly higher ($p<.05$) than the Preferred Blindfold Location mean, and also significantly higher ($p<.05$) than the Nonpreferred Visual Location mean. Although the Preferred Blindfold Location mean was higher than the Preferred Visual Location mean, they did not differ significantly ($p>.05$). The Nonpreferred Blindfold and Visual Memory means were both higher than the Preferred Blindfold and Visual Memory means, but again neither difference was significant ($p>.05$). The Nonpreferred Blindfold Memory mean was lower than the Nonpreferred Visual Memory mean, as were the Preferred Blindfold Memory and Preferred Visual Memory means, but not reliably so ($p>.05$). No significant differences were found between any of the latency means of the Preferred and Nonpreferred groups.

However, the lower means for Visual Location would appear to indicate that visual mediation does not facilitate location recall when the task is learned in the spatial-

tactual modality. The differences between Blindfold and Visual Location means would appear to indicate that vision may have a greater disrupting effect, for this type of task, on gross spatial relationships rather than on finer integrated (the shapes) spatial relationships.

The lower Blindfold Memory means were not as predicted, and Tanne and Yeudall (Ref. Note 2) hypothesized that this may be because subjects in the Visual Memory condition could see what they had drawn and therefore more easily review and retrieve from memory storage the shapes. Further, because the shapes used were familiar geometric ones, retrieval may not have been exclusively from a memory storage of the just completed task, but from a general memory storage for geometrical shapes. This same explanation, of a retrieval from a general memory storage for geometrical shapes, may account for the insignificant differences in means between the Preferred and Nonpreferred groups for Memory.

An analysis of the means for each shape located and remembered showed that three shapes were consistently lower than the other shapes, namely the track-shape, elongated hexagon and diamond. Interestingly, each appears to be among the least verbalizable of the ten shapes. These results seemed to indicate that as a shape becomes more verbalizable the better it is remembered and located correctly, and thus strongly suggest that the verbal hemisphere actively took part in the neural processing and output of the task,

whether it was the Nonpreferred or Preferred group.

The Tanne and Yeudall study does not appear to have eliminated or reduced verbal mediation enough to produce clear differences between the Nonpreferred and Preferred groups for many of the measures. However, the overall better performance by the Nonpreferred group would appear to indicate that the design of the experiment and the procedures used may more effectively reflect the underlying neural organization (the nonpreferred hand beginning first) and allow the spatial-tactual hemisphere to produce an output which limits the amount of mediation by the verbal hemisphere (the Blindfold Location and Memory conditions).

From the Tanne and Yeudall study it would appear that the elimination or reduction of the verbal aspects of the task (the familiar shapes), and retaining the experimental design, would more clearly differentiate between the Nonpreferred and Preferred groups. The use of unfamiliar or nonsense shapes should have the effect of 'forcing' subjects to retrieve the remembered shapes and their location from a memory storage of the just completed task rather than possibly long term or permanent memory and therefore more effectively excluding the verbal hemisphere from actively participating in the task.

Witelson's (1974) nonsense shapes appear to be well suited for such a task. They are not only hard to describe,

even after visual inspection, but also have been successfully used in right hemisphere specialization research (Witelson, 1974, 1976; Gardner, et al., 1977).

The proposed study involved a two group control in which the Preferred group used their preferred hand on the 1st Hand trial, nonpreferred on the 2nd Hand trial, and both hands on the Both Hands trial. The Nonpreferred group used their nonpreferred hand on the 1st Hand trial, preferred hand on the 2nd Hand trial, and both hands on the Both Hands trial. Both groups performed the Location and Memory conditions first blindfolded and then visually. The difference between the Tanne and Yeudall (Ref. Note 2) study and the present one was the use of nine of Witelson's (1974) nonsense shapes and one new nonsense shape rather than the familiar shapes used for the Sequin-Goddard Formboard Task.

The present study attempted to show that the Nonpreferred group would perform better than the Preferred group as measured by latency scores and Location and Memory scores, and further, that Blindfold Location and Memory scores would be better than Visual Location and Memory scores. These predictions were essentially predicated on the assumptions of the split-brain model that states that the right hemisphere is the specialized or dominant hemisphere for processing spatial information; and the degradation hypothesis which states that information through the nonspecialized to the specialized hemisphere is degraded

because of the inherent structure and/or function of either the homologous areas of the nonspecialized hemisphere or the commissures.

METHOD

Subjects

Forty righthanded female and male subjects from an introductory psychology class participated in the experiment to fulfill a course requirement. Two subject groups were employed, a Preferred hand group of fifteen females and five males, and a Nonpreferred hand group of twelve females and eight males.

Handedness was specified in terms of two questions on the Varney and Benton (1975) Handedness Inventory (Appendix I): "Are you righthanded or lefthanded?" and "With which hand do you write?". All subjects answering "Left" or "Mixed" for either question were not included in the experiment.

Apparatus

The apparatus for both groups included the Witelson Nonesense Shape Formboard (Figure 1), as well as a tack board and cover the same size as the formboard. The tack board was constructed so that it fit securely over the cover of the formboard. The formboard was mounted onto a stand which was angled at 70 degrees from the horizontal and away from the subject.

The shapes used in the formboard test were the same as

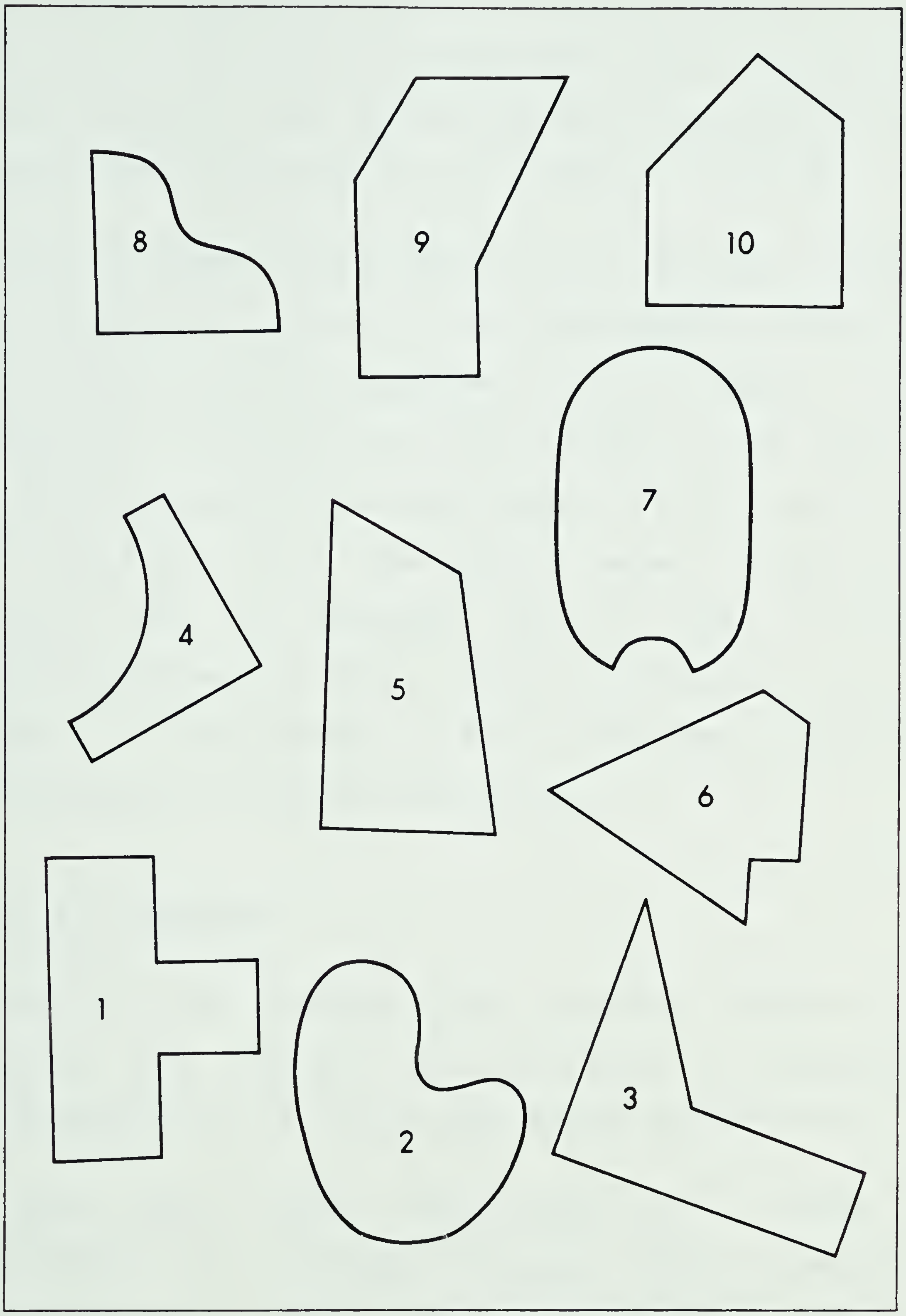

Figure 1. The Outline of the Nonsense Shape Formboard and the Nonsense Shapes and Their Locations on the Formboard.

those used by Witelson (1974), except for the 'track' shape. Since this shape was the same as a shape in the Sequin-Goddard Formboard Task, it was slightly altered by cutting a part circle out of the bottom (see Shape 7 in Figure 1).

The placement of the shapes on the Witelson Nonesense Shape Formboard, as used in this experiment, was such that 'like' shapes, e.g. the cross vs. the 'T' (Shape 1), the rectangle vs. the four sided shape (Shape 5), the circle vs. the totally curved edge shape (Shape 2), etc., were in the same positions as on the Sequin-Goddard Formboard. In addition, both the Witelson Nonsense Shape and Sequin-Goddard boards were of equal overall dimensions, and the thickness of their blocks as well as the depth of the holes on the board were also made equivalent.

Design and Procedure

Half of the subjects were randomly assigned to a Preferred hand condition (P), and half to a Nonpreferred hand condition (N). Subjects were tested individually.

After being seated comfortably at a table and blindfolded, the Witelson Nonesense Shape Formboard was placed directly in front of the subjects who were then read standardized instructions (Appendix II).

The Preferred group subjects first used their right (preferred) hand to place the blocks into their proper

spaces (1st Hand), then their left hand (2nd Hand) and finally, both hands (Both Hands). After the three trials, the tack board was placed over the formboard and the subjects were given a pad of paper (8 cm X 13 cm) and pencil and asked to draw each shape, one at a time, and correctly locate it's position on the board by placing it at it's proper spatial location on the tack board. The subject's drawings and positioning of the drawings on the tack board were scored as measures of Blindfold Location (BL) and Blindfold Memory (BM). The experimenter tacked each drawing to the tack board after the subjects had drawn and chosen a location. When the subjects indicated that they could remember no more shapes or their locations the experimenter removed the formboard. Subjects were then asked to remove their blindfolds, given a letter size sheet of paper (21.7 cm X 27.9 cm), and requested to draw the shapes at the appropriate locations on the paper corresponding to their positions on the formboard. These drawings and their spatial placements were scored as measures of Visual Location (VL) and Visual Memory (VM). When the subjects reported they had drawn and located all of the shapes they were able to remember, the experiment was terminated.

For the Nonpreferred group the procedure was identical except that on the 1st Hand trial they used only their left (nonpreferred) hand and in the 2nd Hand trial they used only their right hand.

The time to complete the latency trials was recorded to the nearest second for each trial. A Total Latency score was obtained by adding the three latency trials together. For purposes of scoring Location and Memory in the Blindfold condition, the tacked drawings of the shapes, as located by each subject on the formboard cover, were glued permanently to the paper by the experimenter immediately after the whole experiment was completed. Great care was taken to preserve not only the original locations, but also the orientations of the drawings.

In both the BL and VL conditions subjects received one point, out of a maximum of ten (the total number of shapes), for each shape placed in a correct location. Correspondingly, in both the BM and VM conditions they received one point for each shape remembered, even if not located correctly, out of a maximum of ten. A drawn shape was considered correct if it could be identified with only one, and not any other, of the formboard shapes, or some other unknown shape. The correct shapes were then scored correct for Location if the drawing was placed in an absolute correct location or correct location in relation to the other drawn shapes. A Total Shapes Located and Remembered score was calculated by adding each of the BL, BM, VL and VM scores together.

The scoring of the BL, BM, VL and VM conditions was

done by the experimenter and an independent scorer. The two scores that were different between the two scorers was resolved by taking the more conservative score in both cases (inter-rater reliability equalled 0.00125).

In addition, questions on the Varney and Benton (1975) Handedness Inventory were scored to permit analysis of the answers. Scoring was in terms of: Right = 1, Mixed = 2, Left = 3, Strong = 1, Moderate = 2, Weak = 3, Don't Know = 0[4]. A total score was taken for Handedness (Questions A and B), Hand Preferences (Questions 1 to 10), Parental Handedness (Questions I and II), Sibling Total Handedness (Question III) and Sibling Average Handedness (the Sibling Total Handedness score divided by the number of siblings).[5]

RESULTS

Table 1 shows the means and standard deviations separately for the males and females within each group for Age, latency trials, Total Latency, and Memory and Location conditions. (Appendix III, Tables 10, 11, and 12 list all the individual subject data.)

The mean age for all forty subjects was 27.775 years, with a range and standard deviation of 18 to 45 years and 7.594, respectively. The mean ages for the Preferred and Nonpreferred groups, and the Preferred group females and males did not differ statistically from one another. Although in both groups the males were, on the average, younger than the females, only the mean ages for the Nonpreferred females and males were significantly different from one another (T=2.387, d.f.=18, p=0.03, two-tail).

Figure 2 shows a plot of the means for the Preferred and Nonpreferred groups for latency trials and Location and Memory conditions. A T-test of independent means (Table 2) was performed between each of the seven pairs of means. Although only the Nonpreferred Blindfold Location mean was significantly higher than the Preferred Blindfold Location mean (T=3.259, d.f.=38, p=0.002, two-tail), a systematic trend was that when averaged across response dimensions, the Nonpreferred group means were better than the Preferred group means.

Table 1

Means and Standard Deviations of the Males and Females, and Combined Males and Females (M+F), within the Preferred and Nonpreferred Groups for Age, Latency Trials, and Memory and Location Conditions (N=40).

	Preferred			Nonpreferred		
	Males	Females	M+F	Males	Females	M+F
Age						
Mean	24.00	31.47	29.60	22.63	28.17	25.95
S.D.	2.92	9.49	8.89	2.88	6.09	5.68
1st Hand						
Mean	913.60	753.87	793.80	677.38	708.00	695.75
S.D.	208.89	282.72	270.40	275.11	371.86	328.91
2nd Hand						
Mean	549.20	682.67	649.30	598.38	570.58	581.70
S.D.	320.56	379.73	362.49	215.43	209.96	206.92
Both Hands						
Mean	277.40	350.00	331.85	321.38	265.50	287.85
S.D.	54.89	160.54	143.75	160.72	85.55	120.59
Total Latency						
Mean	1740.20	1779.87	1769.95	1596.75	1544.08	1565.15
S.D.	312.52	648.24	574.89	508.00	518.62	501.49
Blindfold Location						
Mean	5.00	3.67	4.00	7.00	5.50	6.10
S.D.	2.12	1.80	1.92	1.20	2.47	2.15
Memory						
Mean	8.00	6.87	7.15	8.25	7.67	7.90
S.D.	1.22	1.51	1.50	0.89	1.78	1.48
Visual Location						
Mean	5.60	3.67	4.15	6.13	4.42	5.10
S.D.	1.82	2.19	2.23	2.53	2.61	2.65
Memory						
Mean	8.20	6.47	6.90	7.75	6.33	6.90
S.D.	1.30	1.64	1.71	1.67	2.64	2.36

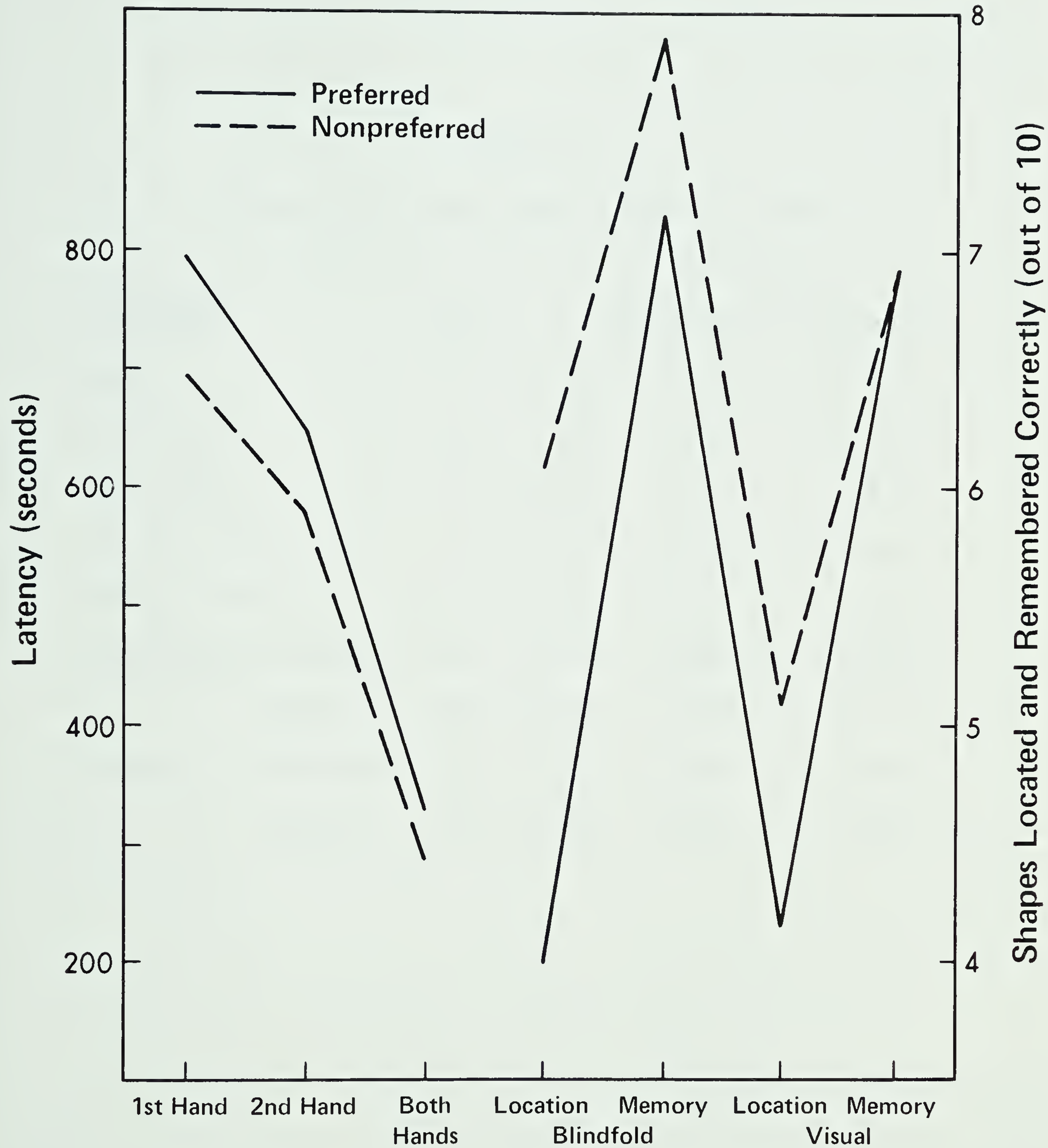

Figure 2. The Means for Latencies (sec) and Shapes Located and Remembered Correctly (out of 10) for the Preferred and Nonpreferred Groups (N=40).

Table 2

T-Tests for Independent Means - N=40.

Variable		d.f.	T	P One-tail	Two-tail
Age		38	1.547	0.065	0.130
1st Hand		38	1.030	0.155	0.310
2nd Hand		38	0.724	0.237	0.473
Both Hands		38	1.049	0.150	0.301
Total Latency		38	1.201	0.119	0.237
Blindfold	Location	38	3.259	0.001	0.002
	Memory	38	1.592	0.056	0.120
Visual	Location	38	1.226	0.114	0.228
	Memory	38	0.000	0.500	1.000

A correlated T-test between Blindfold and Visual Location and Memory means was done (Appendix IV, Tables 13 and 14). Although the Blindfold Location (BL) mean for the Preferred group was lower than the Visual Location (VL) mean, the Blindfold Memory (BM) mean was higher than the Visual Memory (VM) mean, and the Blindfold Location mean was higher than the Visual Location mean for the Nonpreferred group, but none of these means differed reliably. The only means that differed significantly were the Blindfold Memory and Visual Memory means of the Nonpreferred group (T=3.473, d.f.=18, p=0.003), the Blindfold mean being higher.

Figure 3 shows a plot of the means for the Latency Trials and Location and Memory conditions for the males and females of the Preferred and Nonpreferred groups. An analysis of variance with Sex and Group as within variables was done (Tables 3 and 4). For the Latency Trials (Table 3) neither Sex nor Group main effects were significant, but Latency was (F2,72=36.99, p=0.001) and reflected the fact that performance, as measured by time, improved for each latency trial. All the interactions were insignificant.

The Location and Memory conditions analysis of variance (Table 4) showed that the main effect for Sex was significant (F1,36=6.01, p=0.02), with the males overall performance on these measures being better than the females. The fact that subjects remembered more shapes correctly than they located correctly is reflected in the significant main

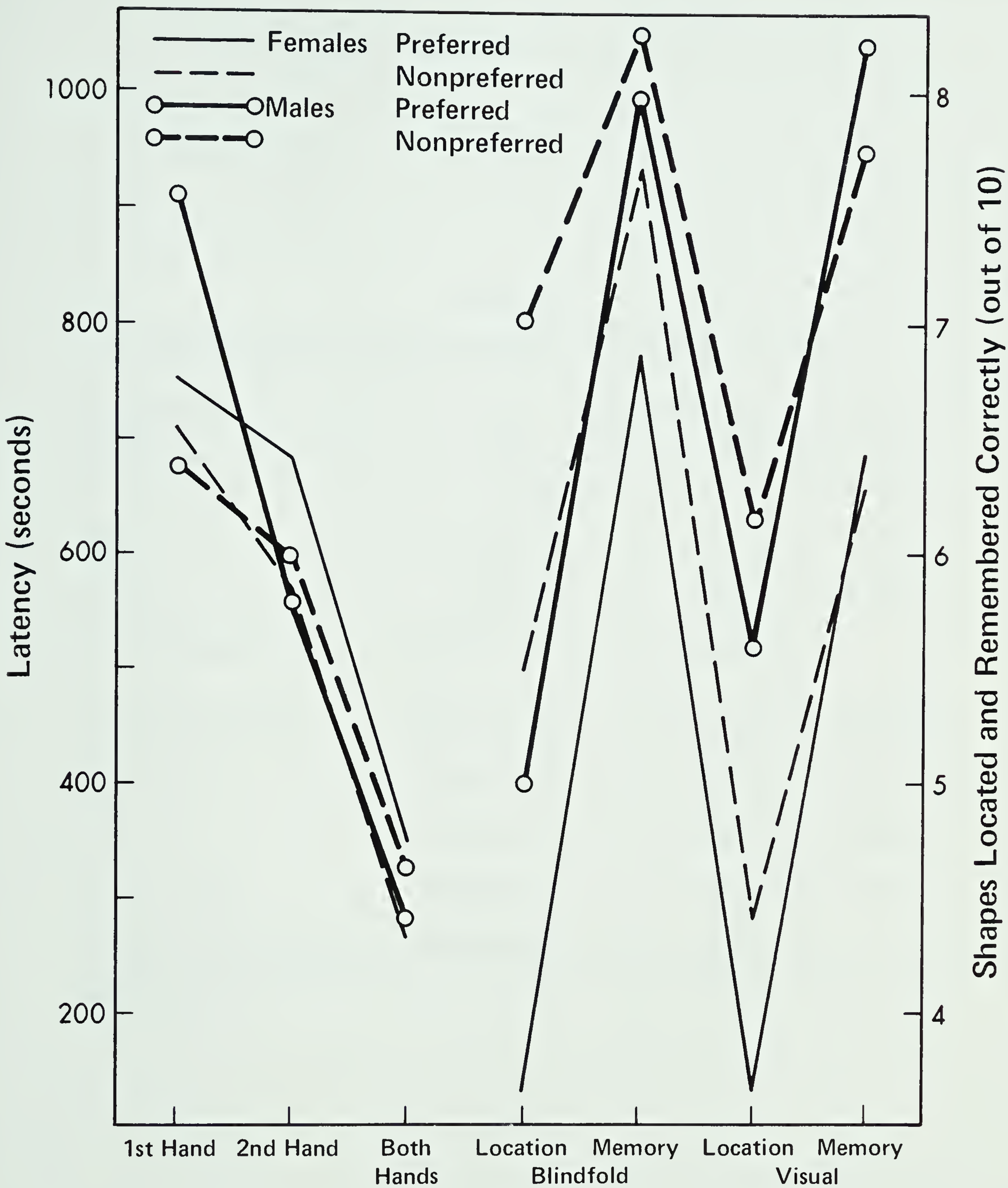

Figure 3. The Means for Latencies (sec) and Shapes Located and Remembered Correctly (out of 10) for the Females and Males of the Preferred and Nonpreferred Groups (N=40).

Table 3

Sex Analysis of Variance for Latency - N=40.

Source	SS	d.f.	MS	F
Sex	33.68	1	33.68	0.00
Group	104303.13	1	104303.13	1.03
S x G	6922.11	1	6922.11	0.07
Subjects(S x G)	3657568.00	36	101599.06	
Latency Trials	3658492.00	2	1829246.00	36.99**
S x L	59157.90	2	29578.95	0.60
G x L	75014.69	2	37507.34	0.76
S x G x L	158863.13	2	79431.56	1.61
Subjects(S x G x L)	3560464.00	72	49450.89	

**p<.001

Table 4

Sex Analysis of Variance for Memory and Location Conditions - N=40.

Source	SS	d.f.	MS	F
Sex	67.70	1	67.70	6.01*
Group	16.36	1	16.36	1.45
SxG	0.45	1	0.45	0.04
Subjects(SxG)	405.48	36	11.26	
Location/Memory	181.27	1	181.27	69.61**
SxL/M	1.36	1	1.36	0.52
GxL/M	11.34	1	11.34	4.35*
SxGxL/M	0.35	1	0.35	0.13
Subjects(SxGxL/M)	93.75	36	2.60	
Blindfold/Visual	6.06	1	6.06	4.38*
SxB/V	2.65	1	2.65	1.91
GxB/V	9.25	1	9.25	6.69*
SxGxB/V	0.01	1	0.01	0.01
Subjects(SxGxB/V)	49.80	36	1.38	
L/MxB/V	0.24	1	0.24	0.84
SxL/MxB/V	0.21	1	0.21	0.72
GxL/MxB/V	0.45	1	0.45	1.58
SxGxL/MxB/V	0.21	1	0.21	0.72
Subjects(SxGxL/MxB/V)	10.23	36	0.28	

*$p<.05$
**$p<.01$

effect for Location/Memory ($F_{1,36}=69.61$, $p<0.01$). The Blindfold/Visual main effect was also significant ($F_{1,36}=4.38$, $p<0.05$), with the Blindfold condition producing higher overall means than the Visual condition. Of all the interactions, only two of the two-way interactions were significant. The Group X Location/Memory interaction was significant ($F_{1,36}=4.35$, $p<0.05$), as was the Group X Blindfold/Visual interaction ($F_{1,36}=6.69$, $p<0.05$). These significant interactions reflected the fact that the Nonpreferred group's overall performance was better than the Preferred's for both Location/Memory and Blindfold/Visual.

A correlation of all the experimental measures, Groups, Sex, Age, The Varney and Benton Handedness Inventory items (see Footnote 5), and Total Shapes Located and Remembered was done (Appendix IV, Table 15). First Hand correlated with Blindfold Memory ($r=0.423$, $p<.01$) and Visual Memory ($r=0.403$, $p<.01$) which indicated that the more time a subject took to do the 1st Hand trial the better they were at remembering the shapes. The significant correlation between Sex and Age ($r=-0.428$, $p<.01$) simply reflected the fact that the females tended to be older, on the average, than the males. Sex and Age did not correlate significantly with any of the latency trials, but did with several of the Location and Memory measures.

Age correlated significantly with Blindfold Location ($r=-0.443$, $p<.01$), Blindfold Memory ($r=-0.414$, $p<.05$),

Visual Location ($r=-0.497$, $p<.01$), Visual Memory ($r=-0.476$, $p<.01$), and Total Shapes Located and Remembered ($r=-0.526$, $p<.01$). It would appear that as subjects got older they tended to perform poorer on these measures of recall. Sex correlated significantly with Blindfold Location ($r=0.365$, $p<.05$), Visual Location ($r=0.370$, $p<.05$), Visual Memory ($r=0.353$, $p<.05$), and Total Shapes Located and Remembered ($r=0.392, p<.05$). This reflected the fact that the females tended to perform poorer on these measures than the males.

Because the above results appear to show a confounding between Age and Sex an *a posteriori* analysis was done on the results of subjects selected for age. A total of twenty-seven subjects were selected ranging in age from 18 to 30 years, with a mean of 23.185 years (s.d.=3.317). No males of the original forty subjects were eliminated to make up the Age-Selected groups. There were twelve subjects in the Preferred group, five were males and seven were females, and fifteen subjects in the Nonpreferred group, eight males and seven females (see Appendix III, Table 10). None of the mean ages between groups or sexes and within groups were reliably different.

Table 5 lists the means and standard deviations of the two Age-Selected groups and for the males and females of each group. Figure 4 shows a plot of the males and females of each group, and Figure 5 of the combined totals of the males and females for each group.

Table 5

Means and Standard Deviations of the Age-Selected Males and Females, and the Combined Age-Selected Males and Females (M+F), within the Preferred and Nonpreferred Groups for Age, Latency Trials, and Memory and Location Conditions (N=27).

	Preferred			Nonpreferred		
	Males	Females	M+F	Males	Females	M+F
Age						
Mean	24.00	22.71	23.25	22.63	23.71	23.13
S.D.	2.92	4.68	3.93	2.88	2.98	2.88
1st Hand						
Mean	913.60	669.71	771.33	677.38	730.14	702.00
S.D.	208.89	277.03	271.11	275.11	292.93	274.52
2nd Hand						
Mean	549.20	619.00	589.92	598.38	563.43	582.07
S.D.	320.56	310.13	301.86	215.43	241.40	220.24
Both Hands						
Mean	277.40	333.57	310.17	321.38	286.14	304.93
S.D.	54.89	198.23	152.86	160.72	88.15	128.75
Total Latency						
Mean	1740.20	1608.00	1663.08	1596.75	1579.71	1588.80
S.D.	312.52	696.64	552.14	508.00	463.16	470.15
Blindfold Location						
Mean	5.00	4.43	4.67	7.00	5.43	6.27
S.D.	2.12	1.40	1.67	1.20	1.72	1.62
Memory						
Mean	8.00	6.86	7.33	8.25	8.00	8.13
S.D.	1.22	1.35	1.37	0.89	1.29	1.06
Visual Location						
Mean	5.60	5.00	5.25	6.13	4.71	5.47
S.D.	1.82	1.15	1.42	2.53	1.98	2.33
Memory						
Mean	8.20	6.86	7.42	7.75	7.14	7.47
S.D.	1.30	1.35	1.44	1.67	1.86	1.73

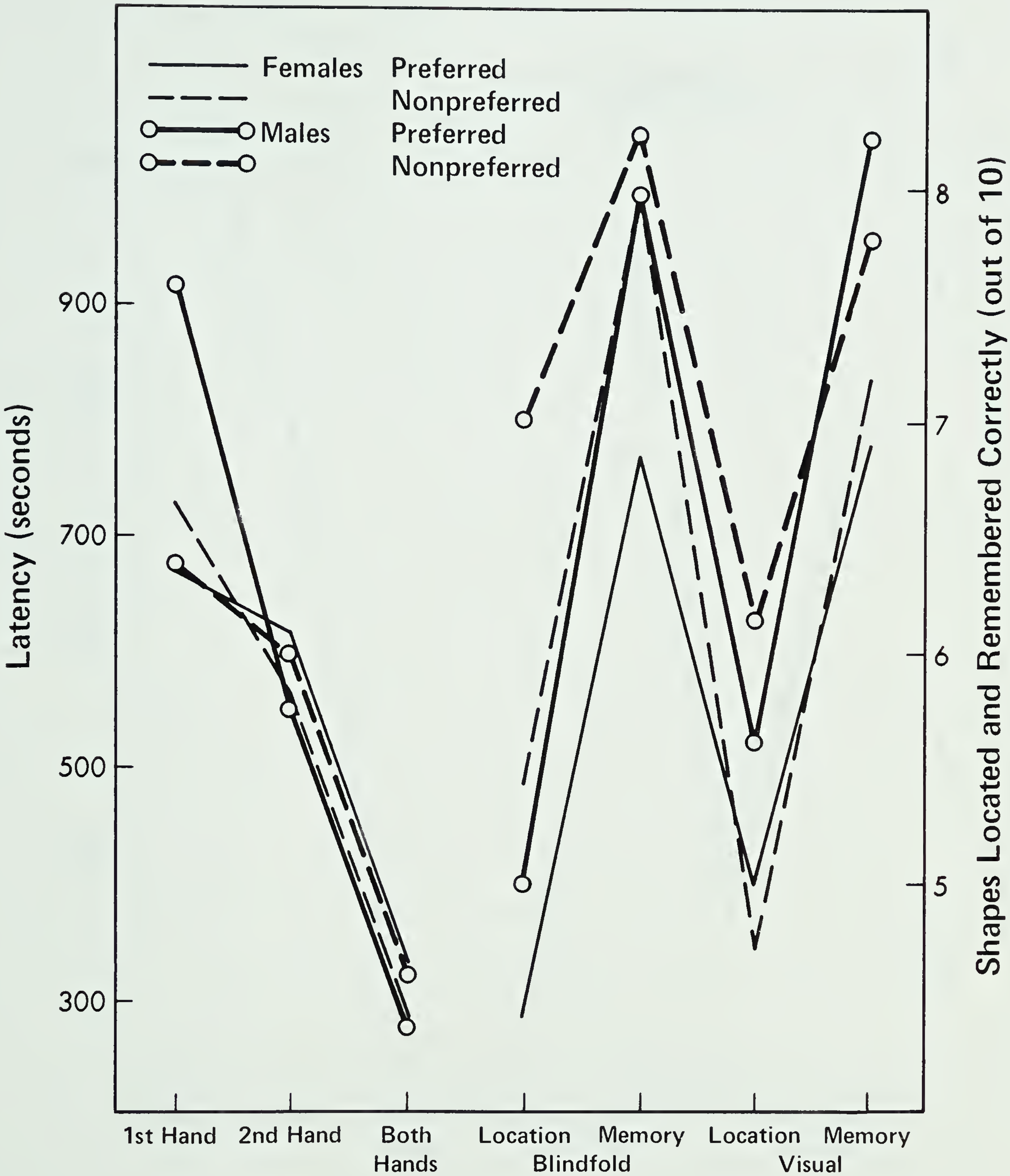

Figure 4. The Means for Latencies (sec) and Shapes Located and Remembered Correctly (out of 10) for the Age-Selected Females and Males of the Preferred and Nonpreferred Groups (N=27).

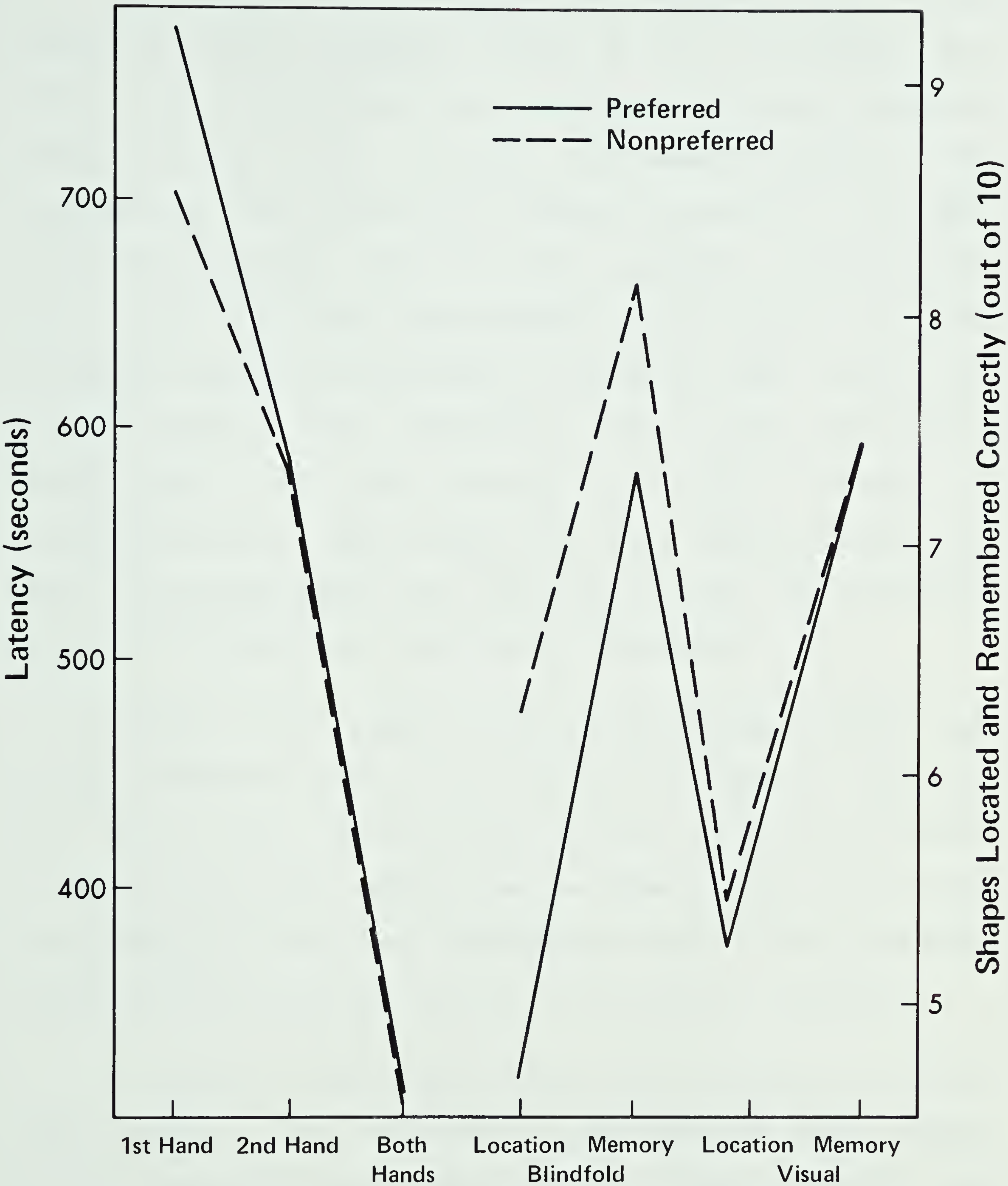

Figure 5. The Means for Latencies (sec) and Shapes Located and Remembered Correctly for the Age-Selected Preferred and Nonpreferred Groups (N=27).

The Age-Selected analysis of variance with Sex and Groups as within variables (Tables 6 and 7) showed that these two main effects were not significant for either the latency trials or the Location and Memory measures. The significant main effects for Latency ($F_{2,46}=35.62$, $p=0.001$) and Location/Memory ($F_{1,23}=76.40$, $p=0.001$) reflected the fact that there was improvement over trials and that subjects remembered the shapes correctly more often than they located them correctly. The only significant interaction was the two-way one for Groups X Blindfold/Visual ($F_{1,23}=6.26$, $p=0.020$), indicating the fact that the Nonpreferred group was better than the Preferred group in the Blindfold and Visual conditions.

T-tests were done to test for differences within each group between the means of the males and females (Appendix IV, Table 16). The male means for the Location and Memory conditions were all higher than the female means, and almost significantly so for the Nonpreferred males in the Blindfold Location condition ($T=2.080$, d.f.=13, $p=0.06$, two-tail).

A T-test was also done to test for differences between the means of the Preferred and Nonpreferred groups (Table 8). The means for the latency trials, Visual Location and Visual Memory were not significantly different from one another. The Nonpreferred Blindfold Location mean was significantly higher than the Preferred Blindfold Location mean ($T=2.512$, d.f.=25, $p=0.009$, one-tail); also, the

Table 6

Sex Analysis of Variance for Age-Selected Subjects for Latency - N=27.

Source	SS	d.f.	MS	F
Sex	9994.85	1	9994.85	0.11
Group	18810.76	1	18810.76	0.20
S x G	5514.85	1	5514.85	0.06
Subjects(S x G)	2121280.00	23	92229.56	
Latency Trials	2627172.00	2	1313586.00	35.62**
S x L	52522.10	2	26261.05	0.71
G x L	31877.43	2	15938.71	0.43
S x G x L	170226.88	2	85113.44	2.31
Subjects(S x G x L)	1696208.00	46	36874.09	

**p<.001

Table 7

Sex Analysis of Variance for Age-Selected Subjects for Memory and Location Conditions - N=27.

Source	SS	d.f.	MS	F
Sex	23.01	1	23.01	3.21
Group	8.17	1	8.17	1.14
SxG	0.01	1	0.01	0.00
Subjects(SxG)	164.99	23	7.17	
Location/Memory	129.13	1	129.13	76.40**
SxL/M	0.27	1	0.27	0.16
GxL/M	1.65	1	1.65	0.98
SxGxL/M	4.85	1	4.85	2.87
Subjects(SxGxL/M)	38.88	23	1.69	
Blindfold/Visual	1.02	1	1.02	0.84
SxB/V	0.07	1	0.07	0.06
GxB/V	7.63	1	7.63	6.26*
SxGxB/V	0.01	1	0.01	0.00
Subjects(SxGxB/V)	28.03	23	1.22	
L/MxB/V	0.22	1	0.22	0.95
SxL/MxB/V	0.20	1	0.20	0.84
GxL/MxB/V	0.60	1	0.60	2.53
SxGxL/MxB/V	0.05	1	0.05	0.20
Subjects(SxGxL/MxB/V)	5.41	23	0.24	

*p<.05
**p<.001

Table 8

T-tests for Independent Means - N=27.

Variable		d.f.	T	P One-tail	P Two-tail
Age		25	0.089	0.465	0.930
1st Hand		25	0.656	0.259	0.518
2nd Hand		25	0.078	0.469	0.938
Both Hands		25	0.097	0.462	0.924
Total Latency		25	0.378	0.354	0.709
Blindfold	Location	25	2.512	0.009	0.019
	Memory	25	1.712	0.050	0.099
Visual	Location	25	0.283	0.390	0.780
	Memory	25	0.080	0.468	0.937

Nonpreferred Blindfold Memory mean was significantly higher than the Preferred Blindfold Memory mean ($T=1.712$, $d.f.=25$, $p=0.050$, one-tail).

Finally, a correlated T-test for the differences in Location and Memory means for each of the groups was done (Appendix IV, Tables 17 and 18). For the Nonpreferred group the Blindfold means were significantly higher than the Visual means for both the Location and Memory conditions ($T=2.286$, $d.f.=13$, $p=0.040$ and $T=2.348$, $d.f.=13$,, $p=0.035$, respectively).

Table 9 lists the mean percentages and standard deviations for each of the shapes located and remembered correctly for the Preferred and Nonpreferred groups and total percentage means of the two groups combined. (See Appendix III, Tables 11 and 12 for the data list.) Figure 6 shows a plot of the total percentage means. A Duncan's Multiple Range Test (Duncan, 1955) on the ten means was done (Appendix IV, Table 19) but only Shape 1 formed an exclusive subset on its own with no overlapping with other shape means ($p<.01$).

Figure 7 shows a plot of the total percentage means for the Preferred and Nonpreferred groups for each of the shapes. A Duncan's Multiple Range Test (Duncan, 1955) on the twenty means was done (Appendix IV, Table 20). No one shape mean formed its own exclusive subset. Although the

Table 9

Mean Percentages and Standard Deviations for Each of the Shapes Located/Remembered Correctly for the Preferred (P), Nonpreferred (N), and Combined Groups (P+N).

	P		N		P+N	
Shape	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	78.7	40.2	85.0	35.4	81.9	37.7
2	56.3	46.0	63.7	47.4	60.0	46.6
3	58.7	48.7	65.0	47.0	61.9	47.7
4	60.0	46.0	73.7	42.0	66.9	43.9
5	48.7	48.8	53.7	48.0	51.2	48.3
6	46.2	48.6	57.5	44.9	51.9	46.6
7	48.7	39.2	57.5	44.1	51.3	41.6
8	57.5	47.3	62.5	48.4	60.0	47.7
9	28.7	43.8	63.7	48.2	46.2	45.9
10	71.2	43.3	65.0	47.9	68.1	45.5

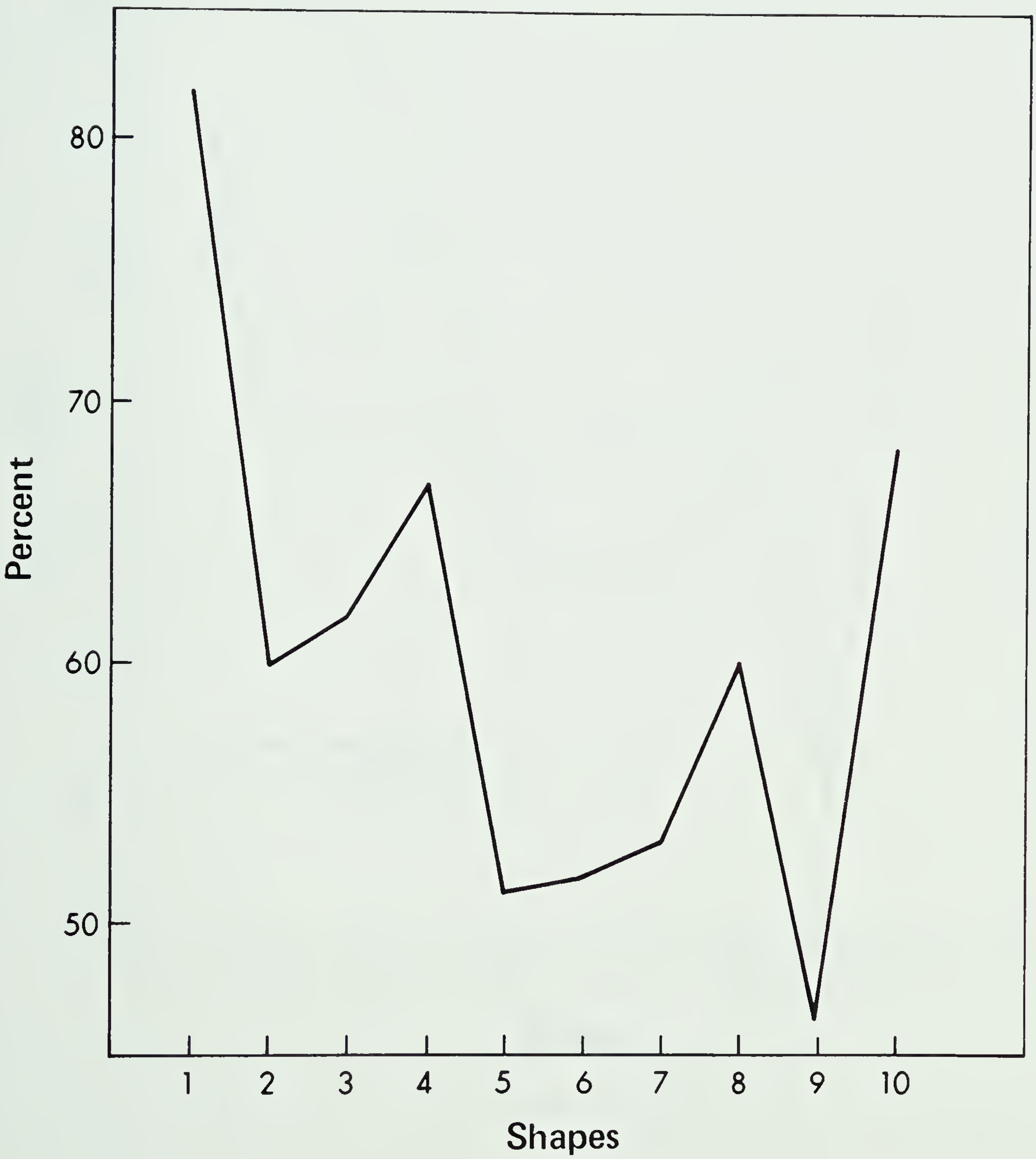

Figure 6. The Mean Percentages of Each Shape Correctly Located and/or Remembered.

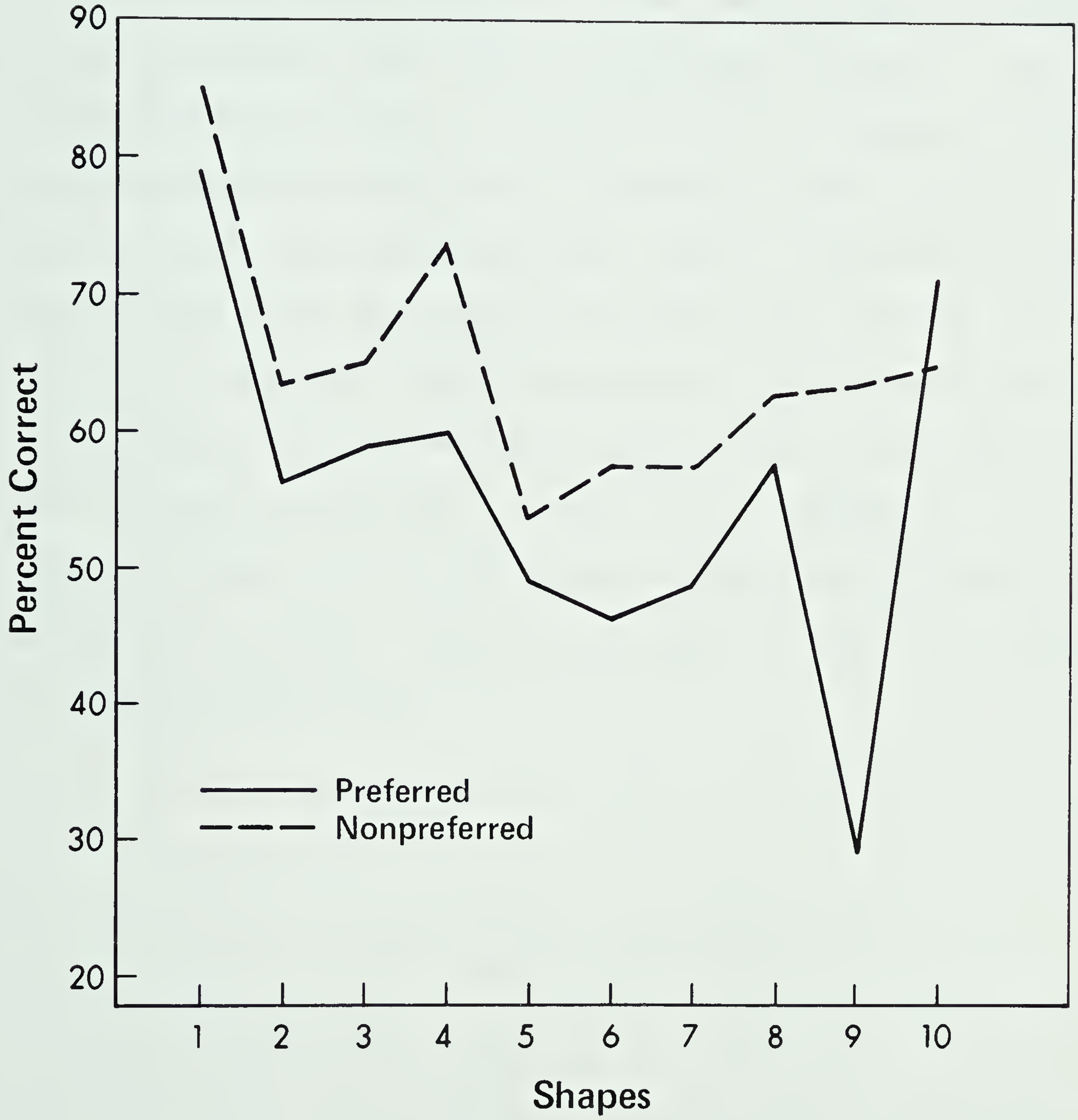

Figure 7. The Mean Percentages of Each Shape Located and/or Remembered Correctly for the Preferred and Nonpreferred Groups.

Nonpreferred group means were higher for nine of the shapes (Shape 10 was lower), only for Shape 9 was there a significant difference between the Preferred and Nonpreferred means ($p<.01$).

An additional, incidental observation made and recorded by the examiner was any spontaneous verbal tags or identifications that a subject gave to a shape. Although such vocalizations were few in number, three subjects did give verbal identifications for shape 1. Subjects 54 and 67 said it was a "T" and subject 99 said "This one is like an E." Two subjects identified shape 2 as "a great big round one" (Subject 67) and "round" (Subject 88). Only one subject (88) verbally identified shape 10 as "square - like a square." There were no other verbal tags or descriptions given to the shapes during the latency trials or Location and Memory conditions.

DISCUSSION

The split-brain model is essentially a 'Gallist' (Marshall, 1973) approach to brain function in human subjects. The model defines the two cerebral hemispheres as being dominant or specialized for certain functions. In particular, as it pertains to the present study, the model states that the left hemisphere processes verbal information and the right spatial information (Gazzaniga, 1970). The model, however, is static rather than dynamic, and therefore does not explain or predict how, for example, verbal and spatial information would be functionally combined to produce a unitary output.

The degradation hypothesis (Filbey and Gazzaniga, 1969; Rizzolatti, et al., 1971) goes a step further by stating that the cerebral commissures are the neural structures that allow passage of information from one hemisphere to the other. And, further, that information travelling from one hemisphere to another is received in a degraded state. Degradation of information may be a function of the commisssures themselves (Filbey and Gazzaniga, 1969), or a function of preprocessing (Rizzolatti, et al., 1971) before the information is transmitted through the commissures to the other hemisphere. The basis for the hypothesis is that the commissures are the structures of integration between the two hemispheres. However, the hypothesis does not explain whether the commissures function to integrate

information between different modalities, act as a transmission structure for information already integrated before transmission, or the transmitter of modality specific information that is integrated with other modalities after being transmitted to the other hemisphere. The possibility exists that any combination of the above integrating functions may occur, however the hypothesis does not explain or predict which, if any, it might be.

Although, in the discussion, the model and hypothesis are found to be the most adequate, on the grounds of parsimony, at explaining the overall results of better performance by the Nonpreferred group for the Memory and Location measures, the homologous processing hypothesis (Witelson, 1974, 1976; Gardner, et al., 1977) is, in terms of an explanation, also discussed.

The homologous processing hypothesis essentially states that both hemispheres are capable of processing spatial information. However, the right hemisphere is specialized or dominant because it is more efficient and therefore more effective at processing spatial information. The hypothesis does not specify that the homologous areas are structurally or functionally the same, only that they are both capable of processing the same types of information. Further, the hypothesis does not explain how spatial and verbal information may be functionally integrated either within the same hemisphere or between hemispheres. Although it does

predict (Gardner, et al., 1977) that information input, processing, and output integrated within the same hemisphere is quantitatively better than information input, processing, and output that involves both hemispheres.

In the ensuing discussion the split-brain model and degradation hypothesis, and the homologous processing hypothesis appear to adequately explain the differences obtained between the two groups for the Memory and Location measures. However, these theories neither adequately nor fully explain other results obtained in the present study. These results are discussed in terms ranging from theoretical speculation (e.g. Effect of Vision) to new and better experimental controls (e.g. Spatial-Tactual/Verbal Processing, and Sex and Age Differences).

Sex and Age Differences

The significant main effect for Sex obtained for the N=40 group analysis of variance for Location and Memory conditions and the significant correlations between Sex and Location and Memory measures were somewhat surprising, and are the result of the consistently lower means of the females for the Location and Memory measures. Further, it was found that there was a significant negative correlation between Age and all the Location and Memory measures which indicated that as subjects got older they tended to do poorer on these measures. Therefore it appears that both Age

and Sex are possible factors in determining performance ability for the present task. The analysis of variance for the Age-Selected (N=27) subjects attempted to establish how sex and age may have independently contributed to the present results but failed to produce a significant main effect for Sex. Although it may thus be possible to conclude tentatively that age was the determining factor for poorer performance, if one examines the means for the males and females for each group (Figure 4) it is apparent that the male means for the Location and Memory conditions are all higher than the female means within each group, although the differences are not reliable.

Knights, et al. (1967) report that the males of both their college and adolescent samples tended to perform better than females which is consistent with the normative data for the Sequin-Goddard Formboard Task. However, their data were based on latency measures and not Location and Memory measures. The present study found that latency differences were random with respect to sex, and only the Location and Memory measures showed consistent differences.

The ontogeny of laterality differences between the sexes has received recent experimental attention and is of relevance to the present data. In a review of the literature, Kammerer (1975) found that most of the studies of somesthesis dealt with sensory differences rather than spatial-tactual perceptual asymmetries. Generally, she

reports that there appeared to be a definite trend toward differences in lateralization for the tactile modality that were a function of sex and age, and that males tended to demonstrate laterality at a later age than females for haptic tasks. The differences were, however, typically not apparent once adolescence was reached. This was in contrast to studies designed to test for hemispheric asymmetry of verbal processes, where males appeared to demonstrate laterality at an earlier age than females.

Witelson (1976), however, found that spatial-tactual lateralization was evident at an earlier age for boys than for girls. Using her nonsense shapes, she tested 200 boys and girls between the ages of 6 and 13 in a dichhaptic paradigm (Witelson, 1974). She found that laterality differences were apparent in boys as early as six, but were not fully apparent in girls until well after the age of ten. This finding is not totally inconsistent with the conclusions arrived at by Kammerer (1975). Kammerer's conclusions were based mainly on studies that dealt with lateralization of tactile sensitivity, whereas Witelson's (1976) study examined cognitive processes.

Witelson (1976) suggests that one of the reasons there is earlier lateralization in males for the spatial-tactual modality is simply because males develope verbal lateralization earlier and this 'invades' the neural tissue of the left hemisphere 'forcing' the right hemisphere to

become specialized for spatial-tactual processing. This conclusion is based on the fact that lateralization of speech processes appear to be complete well before spatial lateralization. Therefore, she concludes that girls have greater bilateral representation until a later age, and possibly even in adulthood, for spatial-tactual processing.

An important consideration here is the possibility that differential neural processing between males and females may also occur in adults (see Witelson, 1976). Witelson notes that several studies dealing with spatial processing demonstrate that there is a tendency for greater left hemisphere participation in spatial tasks by adult females than adult males. Further, differential participation appears to be an exclusive phenomena of spatial tasks, as no consistent differences in laterality between males and females have been found for auditory stimuli of a linguistic and nonliquistic nature (Witelson, 1976).

A study by Gardner, et al. (1977), although not specifically designed to test for sex differences, would appear to be applicable to such a question. They tested 27 male and 33 female University subjects using Witelson's (1974) nonsense shapes in a dichhaptic paradigm to test for reaction times and accuracy of recognition involving unihemispheric (left and right) and interhemispheric (left-right and right-left) transfer of information and output. Gardner, et al. found that there was no significant main

effect for sex for either reaction time or accuracy data, and did not further analyse the data for sex differences (Gardner, personal communication, May 31, 1978).

The results of the present N=27 analysis would appear to be consistent with the above findings that show there are no reliable differences between males and females for overall performance on a spatial task. If the Nonsense Formboard is relatively nonverbal, then greater participation by the verbal hemisphere in females would be of very little benefit or aid in completing the task because the verbal hemisphere would probably have very little additional information. However, for females, the information available from the spatial hemisphere might still be sufficient to produce responses that are of a quality high enough to be nonsignificantly different from those produced by males when all the measures are considered.

Although the N=27 results appear to be consistent with other findings of poorer performance by females on spatial tasks, it is tentative at best. The small number of males and females in each group give rise to the possibility of a sampling error and/or a chance variation in the data. The data do, however, suggest that the experimental design could be used to test for age, sex, and developmental differences if matching samples of sufficient number were used for subjects from preadolescence to adulthood. A study of this

kind perhaps could demonstrate differences reflecting the differential neural development and processing that Witelson (1976) hypothesizes.

Effects of Vision

The lower means for Visual Location and Memory than Blindfold Location and Memory for the Nonpreferred groups (N=40 and N=27) and for Visual Memory for the N=40 Preferred group were as predicted. However, the higher means for the Preferred group for Visual Location and Memory (N=27) and Visual Location (N=40) were not as predicted. These results appear to suggest that vision has a differential effect upon the Preferred and Nonpreferred groups. In particular, the results of the N=27 analysis (see Figure 5) would appear to suggest that vision has a disrupting effect upon the Nonpreferred group when it comes to locating and remembering the shapes whereas it appears to be an aid in locating and remembering the shapes for the Preferred group.

Although the effect that vision has on a haptic task appears to have received very little research attention, studies by Rock and Victor (1964) and Franco and Sperry (1977) are related to this issue.

Rock and Victor (1964) demonstrated what might be considered the classic experiment in stimulus conflict. Subjects viewed a square block through a prism that

distorted it so that it appeared to be a rectangle whose length was twice that of its width, and simultaneously felt the block. Subjects were then either asked to draw the block or make a visual match to comparison blocks. The results overwhelmingly indicated that whether the subjects drew the block or made a comparison match they consistently chose in favor of visual rather than haptic information. The choices were so close to the 2:1 ratio of the visually distorted block that Rock and Victor concluded that subjects may completely disregard haptic information, even if it is the only correct information, when a choice between visual and haptic information is available.

Although the Rock and Victor (1964) study uses stimulus conflict to demonstrate human subjects' reliance upon visual information, the same type of phenomena appears to occur when there is only response conflict, e.g. any design requiring a choice of responses. The Franco and Sperry (1977) study is illustrative of this bias. They had neurologically abnormal and normal subjects haptically examine different geometric shapes and then visually pick out the correct geometric shape from an array of three shapes. A further condition of the study, to check for stereognostic misinterpretation, was to have subjects visually examine a shape and then make a haptic selection from an array of three shapes. The normal subjects made no errors when the shapes were examined visually and identified

haptically, but made several errors when they were examined haptically and identified visually. Although Franco and Sperry only make passing reference to this finding in the results, it is interesting in light of the present study that perhaps vision was disrupting to the haptically learned task. Further, it suggests that perhaps visual information is transferred more effectively than haptic information.

The Rock and Victor (1964) finding, and subsequent research in response conflict that shows a bias toward favoring visual information (Zung, Butler, and Cashdan, 1974), is not consistent with the Franco and Sperry (1977) finding that visual-haptic matches were better than haptic-visual matches. However, it is consistent with the finding that adolescents do better on visual-haptic than haptic-visual matchings; with the differences becoming more pronounced as the shapes become more complex (Lobb, 1965). The Franco and Sperry study used projective and topological shapes in 2-D and 3-D, as well as Euclidean and affine shapes, which may account for the differences. The projective and topological shapes are not easily verbalizable and therefore possibly holistically processed, which is what children appear to do for the so-called familiar shapes. Holistic, rather than verbal, processing of geometrical shapes by children is reflected by the fact that they are able to discriminate between geometrical forms before they can verbalize the defining features of those

forms (Franco and Sperry, 1977).

Therefore, it would appear that visual information is processed in holistic and analytic terms, whereas haptic information is primarily processed in holistic terms when the shapes involved are complex or unfamiliar (nonverbalizable?). Further, if visual processes exclude or ignore haptic information (Rock and Victor, 1964), which is presumably processed in the right hemisphere (Gazzaniga, 1970), it may then instead tap the information that is available in the left hemisphere. However, when the shapes are complex or unfamiliar and perceived haptically, the information processed by the left hemisphere may be very limited which could very well mean that responses dependent upon this information would not be as accurate. Hence, performance deficits or errors (Lobb, 1965; Fanco and Sperry, 1977) occur when unfamiliar geometric shapes are haptically perceived and visually identified.

The present study used nonsense shapes that were presumably unfamiliar to the subjects and therefore were probably largely defined in spatial and holistic (right hemisphere functions) rather than verbal and analytic (left hemisphere functions) terms (Marshall, 1973). Therefore, the Visual condition may depend upon the limited amount of information available in the left hemisphere and the result is lower performance measures when the source of information came from the spatial hemisphere in the Blindfold condition.

An explanation in terms of differential bias would appear to account for the lower Visual Location and Memory means of the Nonpreferred group, but not for the higher means of the Preferred group in comparison to the Blindfold Location and Memory means. It could be argued that the different experimental procedures used for the two groups in the latency trials allowed the Preferred group to encode more information in the left hemisphere. Therefore, when subjects visually performed the Location and Memory tasks, and excluded or ignored right hemisphere processes, the Preferred group had more information available, relative to just haptic information in the Blindfold condition, and this may have allowed them to perform better on the Visual measures.

Although an explanation of the present results in terms of differential bias must be considered entirely speculative at the moment, it does appear to explain the data of this investigation. The paucity of studies designed to investigate the effects of vision on a haptically learned task, and a seemingly total absence of any designed to investigate the fact that vision may have differential effects upon the two hemispheres, makes any explanation of the present results extremely uncertain. Experiments specifically designed to investigate the effects of vision on a haptically learned task and possible differential visual processing in the two hemispheres would no doubt be

of benefit.

It would appear that research workers in this area (e. g. Witelson, 1974, 1976; Gardner, et al., 1977) assume that visual processes act equally upon the two hemispheres. The present results showing a decrease in performance means for the Nonpreferred group and an increase for the Preferred group between Blindfold and Visual conditions seriously questions such an assumption, but however does not answer the question. An experiment to test for the plausibility of differential bias might be to have subjects perform the present task and simultaneously take E.E.G. recordings. A hypothesis of differential bias would predict that right hemisphere activity would be more pronounced relative to left hemisphere activity during the Blindfold condition and the opposite activity patterns would occur during the Visual condition.

Latency Differences

The present insignificant differences in latency means and Total Latency between the two groups was not an expected result. In the Yeudall and Tanne (Ref. Note 1) and Tanne and Yeudall (Ref. Note 2) studies, the latency differences, although producing better overall latency scores for the Nonpreferred groups, were also insignificantly different between the Preferred and Nonpreferred groups. The insignificant differences were attributed to the verbal

factor in the Sequin-Goddard Formboard Task. Therefore it was thought that the substitution of unfamiliar shapes for the familiar ones of the Sequin-Goddard Formboard would remove this factor and allow for a clearer differentiation between the two groups on these measures.

The latency results of the two Sequin-Goddard Formboard Tasks and the Nonsense Shape Task would appear to indicate that performance in the Location and Memory conditions is not dependent upon performance in the latency trials, whether the shapes involved are familiar or unfamiliar. The seeming unimportance of latency performance to predict or determine Location and Memory performance in these formboard studies would appear to be at odds with the clinical literature reporting formboard performance. This literature (e.g. Halstead, 1947; Reitan, 1955, 1959, 1960; Semmes, et al., 1960) shows that latency measures do differentiate between different classes of neurological groupings.

The ability of latency measures on a formboard task to differentiate between different neurological groupings is no doubt one of the reasons that research workers such as Knights, et al., 1967; Knights and Olver, 1967; and Koestline, et al., 1972, used these as measures to test for differences between groups whose dependent measures were varied for verbal labels and/or vision. Generally, these studies report no significant differences within experimental groups when the latency measures were compared.

Knights and Olver used a formboard with unfamiliar shapes, as well as one with familiar shapes, and found that latency measures were significantly different only between the familiar and unfamiliar formboards. Koestline, et al. used the Knights and Olver unfamiliar formboard to test for the effects of verbal labelling between blind, partially blind (but otherwise normal), and normal adolescents. They failed to find any significant differences between the groups when verbal mediation was used, or when visual and/or verbal mediation was used for two other normal groups.

With regard to the present study it was originally thought that a more efficient process system would produce better latency performance by the Nonpreferred group. However, this result was not obtained. The insignificant differences may indicate that both groups were functioning at their potential best, and the potential was equal for both groups. An alternative and perhaps more reasonable explanation may be that the latency conditions are primarily motor processes which appear to be controlled more equally between the hemispheres. Abductive movements appear to be lateralized and adductive movements to be bilaterally represented (Van Der Staak, 1975), therefore the latency trials, which required abductive and adductive muscle responses, would have bilateral involvment in controlling motor reactions. Bilateral involvement and the insignificant latency differences of the present study may indicate that

muscle control is quite well represented in both hemispheres of the brain, whether it is directing left or right arm and hand movements.

A further implication of the bilateral representation of muscle control, and equality over trials, is that if muscle involvement was processing spatial-tactual information in a spatial-type code one might expect smaller or even no differences between the groups on the Location and Memory measures as well, which is not the case for the present study. Gross muscle movement may primarily encode kinesthetic rather than haptic information, and therefore the latency measures may be a reflection of kinesthetic processing ability and Memory and Location measures of haptic processing ability.

Although significant latency differences were hypothesized to result in differences for the Location and Memory measures, it does not necessarily follow that latency differences have to be significant if the Location and Memory measures are. Further, as McLeod (1977b) points out, it does not follow that the nonsignificant latency differences are reflecting the same processing strategy. McLeod presents four models of independent processing and multiprocessing, and his own research leads him to the conclusion that the evidence supports a multiprocessor model that may or may not have "... a processor common to all response production operations" (page 661).

Applied to the present study, the above theoretical formulation means that the latency procedure could be independently processing the placement of the shapes, and what the shapes are like and where they are located. Further, response processes, as reflected by the latency and Location and Memory measures, may also be independent.

The original assumption made that the different latency procedures would allow for differential processing structurally, as measured by latency scores, appears to be disproved by the insignificant differences. It might therefore be concluded that the two groups process the placement of the shapes in the same manner. However, such a conclusion is tentative at best, for as McLeod (1977a) points out, it is not only difficult, on the basis of a measurement such as latency, to distinguish between serial and parallel processing models, but it is equally difficult to distinguish between the kind of processing that may occur within a particular model. Therefore, both groups may process placement of the shapes differently, because of the different latency procedures, but in a manner not sufficiently different to produce significant results between the two groups.

Because subjects were not matched for age and sex, the possibility exists that these factors may be masking different processing strategies employed during the latency

procedure. As previously suggested, the present experimental design, matched for age and sex, could also possibly produce reliable latency differences that could be interpreted as a reflection of different processing strategies. However, the results of the N=27 analysis would make a prediction of significant differences for the latency measures highly speculative. Further, even if such a study should produce significant differences, it still would not tell us much, if anything, about the kind of processing strategy each group employs.

Spatial-Tactual/Verbal Processing

Shape 1, whose mean percentage for correct recall and location was the highest of all ten shapes, was the only shape that formed its own exclusive subset that was significantly different from any other shape percentage mean (Figure 6). Visually examining the ten shapes (Figure 1) it is apparent to the author that Shape 1 is the most familiar of the ten shapes and can be easily identified as a T-shape rotated 90 degrees. And, indeed, Shape 1 was verbally identified by subjects as a "T" twice out of a total of six spontaneous verbalizations.

Tanne and Yeudall (Ref. Note 2) found that the two shapes of the Sequin-Goddard Formboard that were remembered and located correctly the least were the elongated hexagon and track-shape. These two shapes appear to be the least

familiar of the ten Sequin-Goddard Formboard shapes, and were given verbal descriptions rather than verbal labels by subjects that verbally identified them.

The shapes analyses of the two studies would appear to indicate that shapes that can be verbally labelled are remembered and located better than shapes that require a verbal description, which are in turn remembered and located better than shapes which may defy verbal labels or easy descriptions. Milner and Taylor (1972) hypothesize that verbal processing can enhance spatial-tactual processing by adding a verbal tag or label and therefore increasing the amount of information available for later retrieval. The hypothesis would predict that information about a shape, although primarily being processed by the spatial hemisphere, may also be verbally identified and therefore be remembered and located better than a shape that is processed exclusively by spatial processes.

The few spontaneous verbal identifications would appear to indicate that there is a positive relationship between verbal identifications and the ability to remember and locate the shapes correctly. However, there is no way of determining how many subjects may have perhaps felt constrained to vocally identify shapes and therefore used a sub-vocal strategy when performing the recall conditions. Therefore the question of whether verbal processing enhanced the ability to remember and locate the shapes cannot be

determined from the results of this study as it is presently designed.

A possible relationship between verbal identifications and the ability to remember and locate the shapes correctly could perhaps be obtained by having subjects, after completing the Visual condition, write out verbal identifications of the shapes. Based on the limited number of spontaneous vocalizations of the present study it might be predicted that the more verbal identifications a shape receives the better it is remembered and located, and that shapes receiving verbal labels would be remembered and located better than those receiving just verbal descriptions.

Blindfold Location and Memory Measures

The Nonpreferred Blindfold Memory mean of the N=40 analysis was almost statistically higher ($p=0.056$, Table 2) than the Preferred mean, however, the Nonpreferred means for the N=40 Location and N=27 Location and Memory measures were statistically higher than the Preferred means. The predicted better performance by the Nonpreferred group than the Preferred group on the Blindfold Location and Memory measures was essentially based on the split-brain model (Gazzaniga, 1970; Milner and Taylor, 1972) and degradation hypothesis (Filbey and Gazzaniga, 1969; Rizzolatti, et al., 1971).

The split-brain model and degradation hypothesis would predict better performance by the Nonpreferred group because the first spatial-tactual information received (1st Hand trial) would be transmitted directly from the nonpreferred hand to the spatial hemisphere and not be degraded. However, when the same spatial-tactual information is transmitted from the preferred hand to the spatial hemisphere (Preferred group, 1st Hand trial) it must cross between the two hemispheres of the brain via the commissures, which degrade the information (Filbey and Gazzaniga, 1969; Rizzolatti, et al., 1971). Therefore, at the completion of the 1st Hand trial the Nonpreferred group should have information which is more concise and/or precise than the Preferred group.

Although the opposite degradation condition would exist on the 2nd Hand trial for the two groups, it was thought that the Nonpreferred group, which had more concise and/or precise information initially, would be able to more efficiently process the degraded information of the 2nd Hand trial. Implied in such an assumption is the idea that the neurological match for the Nonpreferred group between degraded (2nd Hand) and concise and/or precise (1st Hand) information is more efficiently processed than between concise and/or precise (Preferred, 2nd Hand) and degraded (Preferred, 1st Hand) information.

It was originally thought that more efficient

neurological processing by the Nonpreferred group would be reflected in faster performance for the 2nd Hand trial and also on the Both Hands trial because of a carry-over effect. A further effect predicted on the same neurological assumption was that the Nonpreferred group would recall and locate more shapes correctly than the Preferred group. The insignificant latency differences between the two groups appears to indicate that processing efficiency does not effect latency to any large extent, either during the matching (2nd Hand) or as a carry-over effect (Both Hands). However, the different procedures used for the latency trials of the present study would indicate that the Nonpreferred procedure allows for more efficient neurological processing that is reflected in the differences found between the two groups for the Blindfold Location and Memory measures. The results quite clearly indicate that the Nonpreferred group learned more about the shapes and where they were located than the Preferred group did.

Although the above explanation appears to adequately account for the obtained differences between the two groups for the Blindfold measures there is an alternative explanation in terms of homologous areas that has recently received research attention (e.g. Witelson, 1974, 1976; Gardner, et al., 1977; Smith, et al., 1977). The results of the Gardner, et al. (1977) study (D-D>N-N>D-N>N-D[6]) demonstrated that spatial-tactual information input,

processing, and output by the dominant (right) hemisphere (D-D) was faster and significantly more accurate than input, processing, and output by the nondominant (left) hemisphere (N-N). These conditions were significantly faster and more accurate than the D-N and N-D conditions. Further, input to the dominant hemisphere, processing by both hemispheres, and output by the nondominant hemisphere (D-N) was faster and significantly more accurate than input to the nondominant hemisphere, processing by both hemispheres, and output by the dominant hemisphere (N-D). They concluded that the reaction time data reflected the fact that both hemispheres were capable of processing spatial-tactual information; and that the accuracy data reflected the fact that the spatial hemisphere was more efficient at processing the information than the verbal hemisphere. Further, they feel that these results were obtained because there are preprocessing (Rizzolatti, et al., 1971) or homologous (Witelson, 1974, 1976) areas in both hemispheres that process spatial-tactual information.

Gardner, et al. (1977) believe that the split-brain model, of strict lateralized function, and degradation hypothesis does not account for the results they obtained for the N-N condition. The model and hypothesis would predict the order of results to be D-D>D-N>N-D>N-N; the N-N condition being the slowest and least accurate because it would involve a double crossing between the hemispheres via

the commissures. They propose a model of lateralized neural organization and function that they feel not only accounts for the results of their study but also possibly explains dual processing and functioning (homologous areas) of the two hemispheres for spatial-tactual processing.

Their model proposes that when spatial-tactual information is received directly by either hemisphere it is processed in its own homologous area (D or N), however, more efficiently in the dominant hemisphere (D>N). Further, when a response is required, either hemisphere can direct an output, e.g. a D-N condition would require input and processing of information by the dominant hemisphere and output directed by the nondominant hemisphere. Therefore the N-N condition results in less accurate responses than the D-D condition because the nondominant homologous area is not as efficient, but is faster and more accurate than the D-N or N-D conditions because information processing is integrated within the same hemisphere and does not require commissural transmission of information.

The application of the Gardner, et al. model to the present study would denote the Nonpreferred procedure as D^1-N^2-D/N^3-N (use of the nonpreferred hand on the 1st Hand trial, preferred on the 2nd Hand, both on the Both Hands, and the shapes drawn by the preferred hand), and the Preferred procedure as N^1-D^2-D/N^3-N (preferred hand on the 1st Hand, nonpreferred on the 2nd Hand, both on the Both

Hands, and the shapes drawn by the preferred hand). If an assumption is made that the 1st Hand trial determines subsequent performance on the other latency trials then the notation could be reduced to D-N for the Nonpreferred group and N-N for the Preferred group. The Gardner, et al. model would predict that the N-N condition would produce better results than the D-N condition; which is the opposite to what was obtained in the present study. A more plausible alternative explanation may be that the N^1-D^2-D/N^3 condition does not allow for an efficient match between the information obtained on each of the latency trials, whereas the D^1-N^2-D/N^3 condition does. The latency procedure for the Preferred group may not allow these subjects to efficiently process spatial-tactual information, which could mean that they spent more time directed towards task completion and less time directed towards learning what the shapes were and where they were located. Therefore obtaining lower scores for the Blindfold Location and Memory measures. The above explanation, in terms of efficient processing, is also applicable to the split-brain model and degradation hypothesis.

Although the split-brain model and degradation hypothesis appears to be the more acceptable of the two explanations because it requires fewer neurological assumptions and is therefore more parsimonious, the homologous processing hypothesis does offer some interesting

possiblities for future research using the present blindfold paradigm and formboard apparatus.

The homologous processing hypothesis (Gardner, et al., 1977) would predict that if subjects used only their right hand for the latency trials[7] they would obtain higher Blindfold Location and Memory scores than subjects using only their left hand for the latency trials ($N^1-N^2-N^3-N>D^1-D^2-D^3-N$ or N-N>D-N) because spatial-tactual input, processing, and output would be integrated within the same hemisphere. However, Witelson (1974) notes that the demonstration of homologous processing may depend upon simultaneous input to both hemispheres. Therefore, a more appropriate study to test the hypothesis may be to modify the above proposed study so that subjects simultaneously feel a block(s) with the hand not being used for the latency trials. The split-brain model and degradation hypothesis would predict that D-N>N-N for both proposed studies.

The demonstration of homologous processing may not just depend upon simultaneous input but may also depend upon visual mediation. The Witelson (1974,1976) and Gardner, et al. (1977) studies allowed for full visual inspection of the comparison shapes during the recognition conditions. The results of the Location and Memory conditions of the present study indicate that the Visual condition may have allowed for more left hemisphere output processing of spatial-tactual information than the Blindfold condition did. A

prediction of the results of the proposed studies, based on the homologous processing hypothesis would be that N-N>D-N for the Blindfold measures; and, because of the differential effects of vision, the differences between the two groups for the Visual measures to be even more pronounced.

However, because the Blindfold condition appears to differentially favour right hemisphere processing and the Visual condition left hemisphere processing, it may be more plausible to predict that D-N>N-N for the Blindfold measures and N-N>D-N for the Visual measures. An obtained cross-over result between the two groups for the Blindfold and Visual measures could be explainable, like the results of the present study, in terms of either the split-brain model and degradation hypothesis or the homologous processing hypothesis. However, in light of the present study and the Tanne and Yeudall (Ref. Note 2) study, showing higher, although insignificant, recall means for the Nonpreferred group, a prediction of better scores by the Preferred group on any of the measures does not appear to be very tenable. An obtained result of D-N>N-N for the Blindfold Location and Memory, and Visual Location and Memory measures, for either of the proposed studies, would not necessarily disprove the homologous processing hypothesis, but it would seriously limit its applicability to more general or broader questions of hemispheric organization and functioning.

The Effects of Using Nonsense Shapes

Although Halstead (1947) feels that the Location and Memory scores of the Sequin-Goddard Formboard Task are measures of incidental learning Tanne and Yeudall (Ref. Note 2) seriously questioned the idea; especially as it related to Memory scores. Tanne and Yeudall felt that because the shapes were familiar a subject, upon realizing they were familiar geometric shapes, would 'search' through a long-term memory storage for geometric shapes rather than depend upon a more recent memory storage of the just completed task exclusively.

The significantly higher means for the Blindfold Location measures and the nonsignificantly higher means for the Blindfold Memory measures of the Nonpreferred group indicated to Tanne and Yeudall that the latency procedure differentially favoured the Nonpreferred group because it more closely followed the underlying neurological structure and processing functions of the two hemispheres. Therefore, the nonsignificant differences between the means for the Blindfold Memory condition it was thought was the result of subjects retrieving the memory of the shapes from long-term memory and as a result reducing the differential effects between the two groups.

A further aspect of the nonsignificant differences for the Blindfold Memory scores of the Tanne and Yeudall study

is that the left hemisphere may more actively process integrated spatial-tactual information (the shapes) but not gross spatial-tactual information (the location of the shapes on the formboard). Therefore, the Memory scores would reflect left as well as right hemisphere processing capabilities.

The use of nonsense shapes, in the present study, it was thought would 'force' subjects to locate and recall the shapes from a memory storage of the just completed task rather than long-term memory, and therefore be a better measure of incidental learning. Further, the use of nonsense shapes would possibly more effectively exclude the left hemisphere from actively processing spatial-tactual information.

The significant differences obtained in the present study for the Blindfold Memory scores would indicate that the latency procedure and use of nonsense shapes does differentially favour the Nonpreferred group, however, it does not exclude the possibility of left hemisphere processing as well. The almost identical means for both groups for the Visual Memory condition would indicate that the differential effects favouring the Nonpreferred group are reduced appreciably when vision is allowed. The speculative assumption made earlier that vision allows for a differential expression of left hemispheric over right hemispheric processes, therefore producing higher Visual

Location and Memory means than Blindfold Location and Memory means for the Preferred group, may also mean that the right hemisphere actively processes spatial-tactual information even if it is of an unfamiliar nature. Further, the Blindfold condition may effectively prevent or limit the expression of left hemisphere processing ability, whereas the Visual condition may favour left hemisphere processing.

The use of nonsense shapes that are unfamiliar would appear, at least intuitively, to mean that the Location and Memory scores are measures of incidental learning because the subjects would have no past knowledge of the shapes or where they were located. However, it would appear that subjects attempt to 'match' the unfamiliar to the familiar, and therefore relate present or new information to past memories. The few spontaneous vocalizations by subjects that verbally tagged or described a shape may be evidence of such a process. Therefore it may be difficult, if not impossible, to exclude long-term memory processes from a task such as the present one; and, as a consequence, the Location scores would be the more reliable measure of incidental learning and the Memory scores a mixture of incidental learning and long-term memory processes.

Summary

The 'Gallist' concept of isolated and independently functioning areas of the brain is seen by several workers in

the area of brain research (e.g. Diamond, 1972, 1974; Marshall, 1973; Tucker, 1976; Luria and Simernitskaya, 1977) as having served its purpose and that neural functioning should be viewed in a much more dynamic manner. These research workers feel that models, theories, and research designs should reflect the fact that the brain is an organism whose hemispheres, areas, structures, and processes are dynamic and functionally interdependent.

Marshall (1973) uses the word "leading" (page 463) to describe hemispheric dominance, thereby implying that the two hemispheres are neither competitive (Lansdell and Davie, 1972) nor fully co-operative (Dimond, 1972) with one another. Further, the dominant or leading hemisphere, area, or structure directs and/or determines neural processing strategy that may involve different areas or structures and perhaps both hemispheres.

The present research study attempted to isolate, and thereby demonstrate, right hemispheric specialization for the spatial-tactual modality by changing the latency procedure for the experimental group and using shapes that were unfamiliar and intuitively nonverbal. The overall results (Figures 2 and 5) would appear to indicate that the manipulated latency procedure was successful at isolating and demonstrating right hemispheric specialization for the spatial-tactual modality. However, the shapes analysis (Figures 6 and 7) showing a possible positive relationship

between shapes that appear to be verbalizable and the ability to remember and locate them correctly, would indicate that the procedure and design was not completely successful at isolating spatial-tactual processing from verbal processing. Therefore the possible role that verbal processes may play in performing the Nonsense Shape Formboard Task should also be considered.

Although the differences between the Nonpreferred and Perferred groups for the Location and Memory means were largely defined in terms of efficient matching of spatial-tactual information, it may be that the differences are due to a memory storage and retrieval factor rather than efficient processing per se.

The paradigm used for the Nonsense Shape Formboard and Sequin-Goddard Formboard (Yeudall and Tanne, Ref. Note 1; Tanne and Yeudall, Ref. Note 2) Tasks is quite unlike the classical paradigms used to demonstrate and test for hemispheric specialization and function in normal human subjects. The classic RT, dichotic, and unilateral accuracy paradigms (Broadbent, 1974) generally allow the subjects to know the complete task demands of the study before starting, therefore allowing them to direct their attention to salient features of the stimuli and rehearse responses before they are required. Further, because the paradigms generally require a response immediately following a trial[8], response differences are probably reflecting immediate or short-term

memory processes as well as information processing ability.

The procedure for the Formboard Tasks paradigm however does not inform subjects about the task demands until they have completed a condition and just before the next one. Therefore, subjects are not aware of what the salient features are, or the need to rehearse or deliberately retain a memory of the condition they are completing. Further, the time between the first latency trial and the beginning of the recall measures (about thirty minutes), and between different conditions (about three minutes) represent quite long response delays that also contain interference in the form of instructions for the next condition. Therefore the recall conditions may be measuring long-term memory processes and the latency trials measuring immediate or short-term memory processes.

The fact that the latency differences between the two groups are insignificant may not only indicate that block manipulation and placement are bilaterally represented but that the different latency procedures do not differentially affect immediate or short-term memory processes to any significant degree. Although the overall faster latency performance by the Nonpreferred groups, for all three Formboard Tasks, would appear to indicate there is some advantage.

Better performance for the recall measures on the

Nonsense Shape Formboard Task may very well depend upon interdependent processing by spatial and verbal areas, and the different latency procedures may have allowed for qualitatively different processing strategies for the two groups. The Nonpreferred procedure may tag on verbal processing (Taylor, personal communication), whereas the Preferred procedure may tag on spatial processing to the already processed verbal information. Verbal/spatial rather than spatial/verbal integration for an unknown and unfamiliar spatial-tactual task may not follow the interhemispheric neurological logic of the processing system, and therefore result in nonefficient utilization of the processing systems. Alternatively, the Preferred procedure may allow for independent spatial and verbal processing of the same spatial-tactual information. Therefore, better performance by the Nonpreferred group may be reflecting the fact that the two processes are operationally integrated and stored in memory as a single unit, via commisssural processes, and the poorer performance by the Preferred group reflecting nonintergrated processing and stored in memory as two separate, but related, units.

In terms of the above hypothesis, the experimental procedure of the present study would have allowed for more efficient and effective utilization of the structural organization and dynamic processing of both hemispheres, and therefore verbal as well as spatial processes, not just the

spatial-tactual one. Although the hypothesis does not rule out the possibility of homologous spatial-tactual processing areas within the nonspecialized hemisphere, the results of the present study and the split-brain research (Gazzaniga, 1970) would appear to indicate that such areas may be more limited than hypothesized by such workers as Gardener, et al. (1977). Demonstration of homologous processing areas may be dependent upon short-term memory processes, and therefore not be entirely applicable to the results of the Formboard Tasks. However, the inclusion of homologous processing areas would appear to better explain the differences found for the age and sex factors, and also the possibility of different and/or independent neurological processing strategies.

Because there may be differences in bilateralization, Witelson (1976) feels that

> "... the same neural structures in males and females may have different functions with respect to at least one aspect of cognition during a major period of development. Conversely, the same cognitive process may be mediated by different parts of the brain in boys and girls" (page 426).

Developmentally, the existence and processing capacity of homologous areas may depend upon the amount of verbal lateralization (Witelson, 1974, 1976) that occurs. Earlier and more pronounced verbal, and therefore spatial, lateralization in males (Witelson, 1976) may mean that

females are more equally represented, process-wise, bilaterally. Bilateral spatial-tactual processing areas may result, within the context of the present study, in poorer performance because the two areas would have to 'match' the two encodes; whereas, strongly lateralized processing would control and "lead" (Marshall, 1973) the other homologous processing area.

Unequal development of spatial-tactual processes may also mean that there is unequal deterioration of those same processes. The present study does demonstrate that as the females got older their performance on the memory conditions got poorer. But, because there could be no matched sample of older males, no comparison was made. A comparison of older males and females, matched for age, may not only demonstrate possible sex differences, but also cognitive deterioration both within and between the sexes that could possibly shed some light upon the dynamic organizational structure and function of the processes themselves. The same comparison for young males and females could of course possibly demonstrate the same things, but in a context of developing, rather than deteriorating, processes.

The results of the present experimental paradigm, which is very different from the classical paradigms used for hemispheric laterality studies, appears to have successfully demonstrated spatial-tactual asymmetry of function in normal human subjects. However, the results of the study also

demonstrated areas in need of further research and investigation; such as: differences as they pertain to sex and development, the effects of vision on a haptically learned task, the relevancy of latency to measure performance efficiency or effectiveness, and the role verbal processes play in what appears to be a nonverbal task. More importantly, the fact that the different latency procedures were nonreliably different but produced mean Location and Memory scores that were consistently higher for the Nonpreferred group, does not tell us much about latency as a measure of efficiency and/or effectiveness or as a reflection of the underlying neural structure, organization, and spatial-tactual/verbal processes of the two hemispheres.

The split-brain model may tell us which hemisphere processing for a given modality occurs in, and the degradation hypothesis why ipsilateral processing of information is slower and/or poorer than contralateral processing. However, neither have a strong explanatory effect when it comes to gaining an understanding of how different modality processes, e.g. how spatial and verbal processes in the context of the present study, may interact and be interdependent, both within and between hemispheres. On the basis of the split-brain model and the degradation hypothesis, and the homologous hypothesis (Gardner, et al., 1977), a model of interacting and interdependent processing by the two hemispheres is therefore proposed.[9]

Preprocessing Model

The nonpreferred hand (NP1 and P2) transmits spatial-tactual information directly to a spatial processing area of the right hemisphere. The information is then transmitted, via the commissures, to the verbal processing area of the left hemisphere for verbal processing. The preferred hand (NP2 and P1) transmits spatial-tactual information first to the left hemisphere and then, via the commissures, to the spatial processing area of the right hemisphere. NP2 and P1 result in 'poorer' information being available to the spatial processing area because the information is degraded when it is transmitted between the two hemispheres.

NP1+NP2 results in higher Location and Memory scores because NP1 has processed nondegraded spatial information and can then more easily integrate degraded NP2 information with the already processed NP1 information. Whereas, P1+P2 results in lower scores because it cannot as efficiently and effectively integrate nondegraded P2 information with the degraded P1 information. However, the spatial information, while being transmitted through the left hemisphere (NP2 and P1) also transmits this information to a preprocessing area[10] of the nonspecialized hemisphere.

Gardner, et al. (1977) state that their N-N results indicate "... that both hemispheres were, in fact, capable of processing [the] information, although not equally well"

(page 613). Implied within the statement is the idea that the homologous area is functionally equivalent to the dominant spatial processing area, and the main reason N-N performance is better than D-N and N-D is because "... cross-hemispheric information retrieval decreases accuracy" (page 614).

The term preprocessing, rather than homologous, is used because this area of the spatially nondominant hemisphere is conceived in the model to be not functionally equivalent or to process spatial information the same way as the spatially dominant hemisphere does. The homologous hypothesis conceives the homologous area as being able to process the same spatial information in the same manner as the right hemisphere, and therefore allow for complete spatial processing of the information by the left hemisphere. Therefore, right is better than left hemisphere processing (D-D>N-N) because the homologous area cannot process the same information as well, qualitatively, as the left.

Whereas, the preprocessing area is conceived in this model to process spatial information by features, and the specialized hemisphere processes the same information holistically.[11] Both spatial processing areas process and produce qualitatively 'good' information, but it is different information about the same stimuli.

The preprocessing area receives spatial information

directly from the information being transmitted through the left hemisphere to the spatially dominant right hemisphere and processes the information. However, unlike the holistic processing of the spatial area of the right, the preprocessing area processes the information according to features. The spatially processed features are then transmitted to the verbal area for processing.

The feature information processed by the verbal area is 'good' information, however it may be insufficient, and therefore the verbal area cannot process and integrate the features as a unitary whole. The P1 condition allows feature verbal processing to occur before holistic spatial processing of degraded information can be processed verbally. Separate or partial integration of verbally processed feature and holistic encoding results because the holistic information is degraded and the feature information may not be sufficient, and therefore cannot adequately encode the information as a unitary whole. The P2 condition presents the neurological processing centers with nondegraded information that has to be integrated with degraded information in the spatial hemisphere, and degraded and possible inadequate information in the verbal hemisphere. The verbal integration of nondegraded spatial information could result in nondegraded encodes integrating with degraded encodes, with inadequate ones, with ones that are a combination of feature and degraded integration, or as

a separate encode.

The NP1 condition processes nondegraded information first spatially and then verbally. The NP2 condition processes information in the preprocessing area by features, and as degraded information, holistically, in the right hemisphere. The processed features are added to the already verbally processed spatial information (NP1), and the degraded information is integrated with nondegraded information, both spatially and verbally.

The higher Location and Memory scores by the Nonpreferred group in the Formboard studies would be a function of: 1. nondegraded/degraded integration, 2. verbal processes being tagged on to already processed feature information, and 3. feature encodes being added to holistic encodes.

Nonpreferred performance would produce higher scores for the Memory and Location measures because the spatially dominant hemisphere can more efficiently and effectively integrate nondegraded/degraded than degraded/nondegraded information. Further, the NP1+NP2 condition, when it is an unknown and unfamiliar task, allows the spatial information to be processed according to a neurological logic that requires such information to be processed first spatially and then verbally. Whereas, the P1+P2 condition allows the spatial information to be feature processed by the

preprocessing area and the verbal area before the holistic degraded spatial information can be verbally encoded. Therefore, holistic encoding would have to add on or integrate with the already existing feature encoding; which would mean that the logic of the neurological processing is not followed and the addition of "... some identifiable and memorable verbal tag..." (Milner and Taylor, 1972, page 13) cannot be achieved.

Spatially preprocessed features add to the verbally encoded holistic information because the features are qualitatively 'good' but different. Preprocessing adds different, and therefore more information about the stimuli to the verbally encoded spatial information. The P1+P2 condition, in addition to nondegraded/degraded integration and verbal tagging, results in lower scores because feature encoding cannot be added to any verbal encoding when the task involves totally new and unfamiliar spatial stimuli (P1).

Because the P1 condition does not allow the feature encoding to add any information to existing information, one of the primary functions of the preprocessing area may be eliminated or reduced. Another function of the preprocessing area would be to prime the left hemisphere's neurological systems so that it can act and/or be prepared to be directed by the dominant spatial hemisphere.

Priming by the preprocessing area may vary from preparing the left hemisphere for directions or instructions from the right, to complete left hemispheric processing that is only dependent upon go/no-go instructions from the right. The Formboard Tasks may be illustrative of this point.

The Sequin-Goddard Formboard uses shapes that are, for the most part familiar. During the NP2 and P1 conditions familiar shapes are recognized by their features, therefore fully processed, and the right hemisphere only confirms the encoding and interpretation done by the left. Shapes that are less familiar (e.g. the elongated hexagon) would be encoded spatially and verbally by their features and may depend upon more information from the right hemisphere before it is fully processed. The recognized shapes of the P1 condition can be added to a verbal process because the verbal area already has verbal tags or labels available for these shapes.

Whereas, the less familiar shapes would be verbally processed and stored by their features, which may or may not be added to the verbally encoded degraded holistic spatial information received from the right hemisphere. Further, during the P2 condition nondegraded information must be integrated with degraded information and with verbal information which may be holistically and/or feature encoded.

NP1+NP2 results in higher scores because it not only follows the neurological logic of interhemispheric processing, but also more efficiently integrates the information available from the two trials. However, P1 and P2 can also achieve partial efficient integration when the shapes are familiar and can be recognized spatially and verbally by their features. Feature recognition allows the processing of familiar shapes to bypass the neurological logic of the whole system and therefore allow familiar shapes to be processed efficiently. More efficient integration means that less neurological space is allocated to task demands and more to incidental processing. The Sequin-Goddard shapes were familiar enough to allow for only a small reduction in processing efficiency by the Preferred group, the result of which was lower, but insignificant, scores for the Blindfold Memory measure (Tanne and Yeudall, Ref. Note 2).

Although the model predicts that the more familiar a spatial task is the less difference there should be between the two groups, it also predicts that the less familiar a spatial task is the greater the difference should be between the two groups. The Blindfold Location scores of the Sequin-Goddard Formboard and the Blindfold Memory and Location Scores of the Nonsense Formboard provide evidence of this prediction.

Although the shapes of the Sequin-Goddard Formboard

are, generally speaking, familiar, their location on the board is not. Therefore, the processing of spatial location information must follow the interhemispheric neurological logic of processing spatial information first spatially and then verbally. The P1+P2 condition does not allow the spatial location information to be processed according to this logic, and integrating efficiency, as a consequence, is lowered. Therefore, the significant lower scores are the result of loss of efficiency, not only because nondegraded information cannot integrate efficiently with degraded information, but also because the holistic spatial information cannot integrate with the feature spatial information already processed by the verbal area, or only achieves partial and inefficient intergration. The Nonsense Formboard of the present study uses unfamiliar shapes whose locations are also unfamiliar. The significantly higher scores of the Nonpreferred Blindfold Memory and Location measures therefore are consistent with this prediction.

Further, the model would also predict that familiar shapes would be identified more often than unfamiliar ones. The plot of correctly remembered and located shapes (Figures 6 and 7) would appear to offer proof of this prediction. Shape 1 is, in the opinion of the author, the most recognizable of all the shapes, and can also be easily verbally labelled as a 'T'. Therefore, because of its familiarity and verbal quality, it should be identified more

often than any of the other shapes. The shapes analysis shows that Shape 1 was not only remembered and located correctly more often than any other shape on the board, but significantly so.

A model in order to have any value should not only be able to account for data of a specific research study, but also data of other studies. Therefore, the model just proposed will be applied to the results of the Gardner, et al. (1977) study.

Gardner and her associates used Witelson's (1974) nonsense shapes, which they considered unfamiliar and nonverbal, and did not consider or try to account for verbal processes (Gardner, personal communication). The results of the present study would indicate that verbal processes cannot be isolated or excluded from processing even unfamiliar or nonverbal spatial stimuli.

The dichotic paradigm which they used blocks or interferes with interhemispheric transmission of information (Kimura, 1967), therefore verbal processing of right hemisphere spatial information (the D-D, D-N, and N-D conditions) would be excluded and/or reduced. As a consequence, verbal processes may not be able to tag on any additional information to the spatial processing of the right hemisphere. The dichotic paradigm would not interfere with intrahemispheric processing (N-N), therefore

integration processing within the left hemisphere would be the only experimental condition to have complete and ready access to the verbal area.

However, since the task is primarily a nonverbal one, the hemispherically integrated D-D condition can produce statistically better scores because additional verbal tags would not add much to the nondegraded information already available for a response. Further, the N-N scores are better than the D-N or N-D scores, not only because of hemispheric integration of processes, but also because D-N and N-D require commissural transmission of primary information that would be subject to degradation. However, the better N-N scores may not just be a function of degradation processes but also the result of the dichotic paradigm blocking or interfering with verbal processing of right spatial information. These factors would have the effect of lowering D-N and N-D scores and/or raising N-N scores. Therefore, the Gardner, et al. results may be measuring not only spatial-tactual processing abilities of both hemispheres, but also spatial/verbal processes in the N-N condition and the exclusion of verbal processes in the other conditions. The results indicated to Gardner and her associates that a spatial homologous area of the left hemisphere processed the same information as the right hemisphere, but because of dominance processes it was qualitatively 'poorer'. Therefore, although the homologous area produces

qualitiatively 'poorer' information it is still functionally equivalent to the spatial processing area of the right hemisphere.

If the functionally equivalent and qualitatively 'poorer' homologous process area was substituted for the preprocessing area of the present proposed model, and verbal processes accounted for, D-N>N-D results would not be predicted from the modified model. The N-D condition, which would have input and spatial/verbal processing integrated within the left hemisphere and only one interhemispheric crossing, should produce better results than the D-N condition. The D-N condition not only requires a double crossing between the hemispheres, but also, because of the dichotic paradigm, has its access to verbal areas blocked or interfered with. The modified model, assuming that verbal processes do play a role in processing spatial information, would predict that N-D>D-N; which was not obtained in the study. However, preprocessing and qualitatively 'good', but different, processing in the proposed model does predict and account for not only better performance by the D-N condition than the N-D condition, but also that D-D performance will be better than N-N performance, which in turn are better than the D-N and N-D conditions.

Although the proposed preprocessing model can be applied to the Gardner et al. (1977) study, the strength of the model would depend upon its applicability to other

spatial-tactual studies, and perhaps, to other modalities. However, the model, highly speculative in some aspects, and post hoc, has as a basis a theoretical foundation that has been well researched and documented.

The model accounts for degradation processes, and more importantly, adheres to the split-brain model of lateralized function on several levels. Spatial processing is primarily, but not exclusively, the function of the right hemisphere. The right hemisphere is the dominant hemisphere for spatial processing because it processes the information holistically (a right hemisphere function), and the preprocessing area processes the information analytically (a left hemisphere function). Unfamiliar stimuli are processed by the right hemisphere and familiar by the left. (See Marshall [1973] for a review of some of the distinctions and similiarities between the two hemispheres.)

Although the above examples point out the differences between the two hemispheres, the familiar-unfamiliar distinction can be used as an example of how dominance processes can become indistinguishable between the two hemispheres. As an example, a totally unfamiliar stimulus is transmitted to the spatially dominant right hemisphere and to the preprocessing area of the left hemisphere. The right hemisphere holistically processes the information and repeated presentations of the same stimulus are also processed holistically, and added to previously processed

holistic encodes, therefore reinforcing it.

The preprocessing area analytically processes the information, but because it is unfamiliar it cannot put the separate features together to form a unitary whole. However, repeated presentations allow the preprocessing area to not only reinforce the previous separate features, but to add new features, and eventually to put all the features together to form a unitary whole. Therefore, any further presentation of the stimulus means that the preprocessing area can identify specific features that belong to a specific shape that is recognizable and familiar, and can therefore be fully processed by the left hemisphere.

The preprocessing model proposes that the preprocessing and the verbal areas are directly linked, as a consequence the information of a unitary verbal encode of unfamiliar stimulus would have a direct relationship with preprocessing functions (assuming the ideal and hypothetical situation where no information is available from the right hemisphere). Therefore, as an unfamiliar shape becomes more familiar it also becomes more verbalizable, and the distinction between unfamiliar/nonverbal and familiar/verbal breaks down.

Marshall (1973) notes that although verbal and familiar processing appear to be functions of the left hemisphere, and nonverbal and unfamiliar processing functions of the

right, it is often hard to distinguish whether a stimulus will be processed by a particular hemisphere on the basis of verbalizability and/or familiarity. The preprocessing model predicts that a hemispheric shift in processing can occur, and accounts for the possible relationship between verbalizability and familiarity.

Although the analytic processing by the preprocessing area adheres to the split-brain model, the actual processing of features, reinforcement of features, and the addition of new features to already existing ones, owes more to verbal learning theory than to brain function theory.

Shimp (1976) notes that tradionally free recall of word lists are measured by "... the increase over trials in the number of remembered words..." (page 116). Each word is treated as a unit (feature), and the more words recalled over trials were "... viewed as a by-product of the increase in the strengths of the invariant units..." (page 116). However, he also notes that when these same recall words (features) are subjected to cluster analysis the words (features) join with other words (features) to form a unit made up of more than one word (metafeature). Each recall trial added more words (features) to a unit (metafeature) until the unit reached seven, plus or minus two words (shape). Applied to the preprocessing model, as the bracketed words indicate, each feature of a shape is added to by successive presentations, the addition of new features

produces metafeatures which are added to until all the metafeatures are joined to form a unitary whole.

However, the exact clustering of words (features) into units (metafeatures) varied from individual to individual, therefore indicating that the processing strategy used by each individual was different. Individual processing strategy by the preprocessing area may account for the differences found between the males and females of the present study.

The preprocessing area could be hypothesized to be a vestigial process retained in the right hemisphere after lateralization has been completed. The degree of lateralization achieved for any one individual would depend upon genetic and environmental factors. The genetic code would determine how much, if any, lateralization occurs. (The ideal assumption is made that the genetic code only results in left hemisphere verbal dominance and right hemisphere spatial dominance.) However, the turning on of the genetic code for lateralization may be controlled by a sex linked factor, which could mean that males and females undergo lateralization at different stages of development.

Later lateralization in females (Witelson, 1974, 1976) may mean that the neural tissue might have lost some of its elasticity and therefore retains a larger amount of neural tissue in the preprocessing area devoted to processing

spatial information. A larger amount of neural tissue would mean, according to the preprocessing model, that the females would be able to process familiar/verbal information, if not better, at least just as well. Witelson (1974, 1976) cites several studies that demonstrate that females are consistently, if not always significantly, better than males for verbal tasks. Further, the females of the Sequin-Goddard Formboard Tasks (Yeudall and Tanne, Ref. Note 1; Tanne and Yeudall, Ref. 2) demonstrated no consistent differences when the shapes were familiar, but did so in the present study when the shapes were unfamiliar.

The degree of lateralization would not be wholly determined by a genetic factor but also by environmental factors. Neurological trauma, especially during the period when the brain appears to be quite plastic, may result in damage that either does not allow for complete lateralization or only partial lateralization (Subirana, 1969). Therefore, the neurological capacity of the preprocessing area could vary depending upon sex, genetic, and developmental factors. Variations in the capacity would mean that different individuals and preprocessing areas would process the same information differently.

The combination of the above factors could lead to the conclusion that preprocessing capacity is so varied that no consistent results can be achieved. However, because the subjects used in most research of this kind are normal, the

factor of neurological trauma can probably be disregarded. The degree of lateralization can also probably be disregarded when subjects are selected, for example by a questionnaire in the present study, and matched according to well known lateralization criteria.

The sex factor, however cannot be disregarded. The consistently lower scores of the females in the present study would appear to indicate that female processing strategy was 'poorer'. However, strategy may not be 'poorer' but rather different, and incapable of meeting the demands of the task to the same degree as the male's strategy did.

Consistent different processing strategies would suggest that a model be constructed to account for sex differences, and possibly individual and age differences. However, the preprocessing area of the model allows for neurological differences and therefore can account for different strategies that are related to sex, age, and development, and even individual differences at a more molecular level.

Ideally a model should account for all the data of a study, however the proposed Preprocessing Model does not, for the present study, account for the effects of vision on a haptically learned task, and the insignificant latency differences. Although the Preprocessing Model adds nothing to the explanation of these results, these explanations do

not reduce the explanatory powers of the Model wherever it is applied.

The present study may be supposed to demonstrate the validity of using the split-brain model and degradation hypothesis as a basis for understanding and designing experimental research of lateralized hemispheric functioning. But it also demonstrates their limitations, and a need for models and hypotheses that more adequately reflect the dynamic nature of intra- and interdependent hemispheres in normal human subjects.

FOOTNOTES

1. The term dichotic is used in this paper for the auditory, visual and somesthetic-tactual modalities unless specifically noted otherwise. Although technically the visual modality for this research paradigm is dicoptic, and the somesthetic-tactual is dichaptic, most of the current literature just uses the term dichotic for all the modalities.

2. Kimura (1967) uses the term "occlusion mechanism" (page 171) which means to close or stop, and therefore implies that in the dichotic paradigm ipsilateral information cannot even get into the contralateral processing area. This is not the case, for information does get through; only not as much and/or as accurately - possibly because of fewer nerve fibres and an inhibitory mechanism. Therefore the terms "restricted" and "inhibited" are used instead which would allow for some information to be processed but possibly of a limited or inaccurate nature.

3. This idea can be compared directly to the TOTE system (Pribram, 1971).

4. No subject answered "Don't Know' for any of the Questions.

5. Totals on the Varney and Benton (1975) Handedness Inventory were used because some questions (e.g. Question A, Question 1) were answered identically by all subjects. Therefore resulting in the statistical condition of zero variance.

6. Gardner, et al. (1977) use ND to denote either nondominant input and processing or nondominate direction of output. The present paper uses only N to denote the same processes.

7. I would like to thank Dr. L. T. Yeudall for suggesting this procedure of testing for hemispheric functioning.

8. Although most of the classical paradigms require an immediate response upon completion of a trial, some designs employ response delays and/or interference between the end of a trial and a response. Other studies (e. g. Gardner, et al., 1977) employ varied response demands that change randomly from trial to trial and usually inform the subject what type of response is required at the end of the trial.

9. In the proposed model it is assumed that processing for the Both Hands condition (NP3 and P3) for both groups is either the same, or if not, simply a carry-over effect of the first two latency trials.

10. Rizzolatti, et al. (1971) also use the term preprocessing. However, they use the term to mean an area of one hemisphere that filters or prepares information before it is transmitted, via the commissusres, to the other hemisphere, which also may or may not be a part of the degradation process.

11. The idea of feature, unit, or analytic processing by the left hemisphere is well documented in the brain function literature. Marshall (1973) feels that one of the main processing distinctions between the two hemispheres is that the left processes information analytically and the right holistically.

12. Subjects usually just asked questions that were meant to clarify the instructions. However, occasionally subjects asked how many blocks there were or what type of shapes they were. These questions were not answered .

REFERENCE NOTES

1. Yeudall, L. T. and Tanne, G. Use of preferred and nonpreferred hands and their effects on the Sequin-Goddard Formboard Task. Unpublished manuscript, University of Alberta, 1973.

2. Tanne, G. and Yeudall, L. T. Tactual and visual effects on a Sequin-Goddard Formboard Task. Unpublished manuscript, University of Alberta, 1977.

REFERENCES

Berlucchi, G., Heron, W., Hyman, R., Rizzolatti, G. and Umilta, C. Simple reaction times of ipsilateral and contralateral hand to lateralized visual stimuli. Brain, 1971, 94, 419-430.

Bogen, J. E. and Gazzaniga, M. S. Cerebral commissurotomy in man: Minor hemisphere dominance for certain visuospatial functions. Journal of Neurosurgery, 1965, 33, 394-399.

Brinkman, J. and Kuypers, H. G. J. M. Splitbrain monkeys: cerebral control of ipsilateral and contralateral arm, hand and finger movements. Science, 1972, 19, 536-539.

Broadbent. D. E. The role of auditory localization in attention and memory span. Journal of Experimental Psychology, 1954, 47, 191-196.

Broadbent, D. E. Division of function and integration of behavior. In F. O. Schmitt and F. G. Worden (eds.), The Neurosciences: Third study program. Cambridge, Mass.: The MIT Press, 1974.

Dimond, S. The double brain. London: Churchill Livingston, 1972.

Dimond, S. J. Hemisphere function in the human brain: An introduction. In S. J. Dimond and J. G. Beaumont (Eds.), Hemisphere function in the human brain. London: Elek Science, 1974.

Duncan, D. B. Multiple range and multiple F tests. Biometrics, 1955, 11, 1-42.

Filbey, R. A. and Gazzaniga, M. S. Splitting the normal brain with reaction time. Psychonomic Science, 1969, 17, 335-336.

Franco, L. and Sperry, R. W. Hemisphere lateralization for cognitive processing of geometry. Nueropsychologia, 1977, 15, 107-114.

Gardner, E. B., English, A. G., Flannery, B. M., Hartnett, M. G., McCormick, J. K. and Wilhelmy, B. B. Shape-recognition accuracy and response latency in a bilateral tactile task. Neuropsychologia, 1977, 15, 607-616.

Gazzaniga, M. S. The Bisected Brain. New York: Appleton-Century-Crofts, 1970.

Gazzaniga, M. S., Bogen, J. E. and Sperry, R. W. Laterality effects in somesthesis following cerebral commissurotomy in man. Neuropsychologia, 1963, 1, 209-215.

Halstead, W. C. Brain and Intelligence. Chicago: University of Chicago Press, 1947.

Kammerer, B. L. The development of hemispheric asymmetry and somesthesis (Doctoral dissertation, Cornell University, 1975). Dissertation Abstracts International, 1975, 36, 1B-982b. (University Microfilms No. 75-18,134.)

Kimura, D.. Functional asymmetry of the brain in dichotic listening. Brain, 1967, 3, 163-178.

Knights, R. M., Hyman, J. A. and Atkinson, B. R. The effects of verbal and tactual pretraining on a formboard task. Canadian Psychologist, 1967, 7a, 384-390.

Knights, R. M. and Olver, M. R. Effects of verbal mediators on a nonvisual formboard task. Journal of Consulting Psychology, 1967, 31, 244-247.

Koestline, W. C., Dent, O. B. and Giambra, L. M. Verbal mediation on a nonvisual formboard task with blind, partially sighted, and sighted subjects. Journal of Consulting and Clinical Psychology, 1972, 38, 169-173.

Lansdell, H. and Davie, J. C. Massa intermedia: Possible relation to intelligence. Neuropsychologia, 1972, 10, 207-210.

Lobb, H. Vision versus touch in form discrimination. Canadian Journal of Psychology, 1965, 19, 175-187.

Luria, A. R. and Simernitskaya, E. G. Interhemispheric relations and the functions of the minor hemispheres. Neuropsychologia, 1977, 15, 175-178.

Marshall, J. C. Some problems and paradoxes associated with recent accounts of hemispheric specialization. Neuropsychologia, 1973, 11, 463-470.

McLeod, P. Parallel processing and the psychological refractory period. Acta Psychologica, 1977a, 41, 381-396.

McLeod, P. A dual task response modality effect: Support for multiprocessor models of attention. Quarterly Journal of Experimental Psychology, 1977b, 29, 651-667.

Milner, B. Interhemispheric differences in the localization of psychological processes in man. British Medical Bulletin, 1971, 27, 272-277.

Milner, B. Hemispheric specialization: Scope and Limits. In F. O. Schmitt and F. G. Worden (Eds.), The neurosciences: Third study program. Cambridge, Mass.: The MIT Press, 1974.

Milner, B. and Taylor, L. Right hemisphere superiority in tactile pattern-recognition after cerebral commissurotomy: Evidence for nonverbal memory. Neuropsychologia, 1972, 10, 1-15.

Mountcastle, V. B. Interhemispheric relations and cerebral dominance. Baltimore: John Hopkins Press, 1962.

Pribram, K. H. Languages of the brain: Experimental paradoxes and principles in neuropsychology. Englewood Cliffs, New Jersey: Prentice-Hall, 1971.

Reitan, R. M. Investigation of the validity of Halstead's measures of biological intelligence. American Medical Association Archives of Neurology and Psychiatry, 1955, 73, 28-35.

Reitan, R. M. Effects of brain damage on a psychomotor problem-solving task. Perceptual and Motor Skills, 1959, 9, 211-215.

Reitan, R. M. The significance of dysphasia for intelligence and adaptive abilities. Journal of Psychology, 1960, 50, 355-376.

Rizzolatti, G., Umilta, C. and Berlucchi, G. Opposite

superiorities of the right and left cerebral hemispheres in discriminative time to physiognomical and alphabetical material. Brain, 1971, 94, 431-442.

Rock, I. and Victor, J. Vision and touch: An experimentally created conflict between the two senses. Science, 1964, 143, 594-596.

Semmes, J., Weinstein, S., Ghent, L., and Teuber, H.-L. Somatosensory changes after penetrating brain wounds in man. Cambridge, Mass.: Harvard University Press, 1960.

Shimp, C. P. Organization in memory and behavior. Journal of the Experimental Analysis of Behavior, 1976, 26, 113-130.

Smith, M. O., Chu, J. and Edmonston, W. E., Jr. Cerebral lateralization of haptic perception: Interaction of responses to braille and music reveals a functional basis. Science, 1977, 197, 689-690.

Sperry, R. W. Split-brain approach to learning problems. In G. C. Quarton, T. Melnechuk and F. O. Schmitt (Eds.), The Neurosciences: A study program. New York: The Rockefeller University Press, 1967.

Sperry, R. W., Gazzaniga, M. S. and Bogen, J. H. Interhemispheric relationships: The neocortical commissures; syndromes of hemisphere disconnection. In P. J. Vinkken and G. W. Bruyn (Eds.), Handbook of Clinical Neurology, Vol. 4. New York: John Wiley, 1969.

Subirana, A. Handedness and cerebral dominance. In P. J. Vinkken and G. W. Bruyn (Eds.), Handbook of

Clinical Neurology, Vol. 4. New York: John Wiley, 1969.

Teuber, H.-L. Why two brains? In F. O. Schmitt and F. G. Worden (Eds.), The neurosciences: Third study program. Cambridge, Mass.: The MIT Press, 1974.

Tucker, D. M. Sex differences in hemispheric specialization for synthetic visuospatial functions. Neuropsychologia, 1976, 14, 447-454.

Van Der Staak, C. Intra- and interhemispheric visual motor control of human arm movements. Neuropsychologia, 1975, 13, 439-448.

Varney, N. R. and Benton, A. L. Tactile perception of direction in relation to handedness and familial handedness. Neuropsychologia, 1975, 13, 449-454.

Weinstein, S. Differences in effects of brain wounds implicating right or left hemispheres. In V. B. Mountcastle (Ed.), Interhemispheric relations and cerebral dominance. Baltimore: John Hopkins Press, 1962.

White, M. J. Laterality differences in perception: A review. Psychological Bulletin, 1969, 72, 387-405.

Witelson, S. F. Hemispheric specialization for linguistic and nonlinguistic tactual perception using a dichotomous stimulation technique. Cortex, 1974, 10, 3-17.

Witelson, S. F. Sex and the single hemisphere: Specilization of the right hemisphere for spatial processing. Science, 1976, 193, 425-427.

Witelson, S. F. Developmental dyslexia: Two right hemispheres and none left. Science, 1977, 195, 309-311.

Zung, B. J., Butter, E. J. and Cashdan, S. Visual-haptic form recognition with task delay and sequenced bimodal input. Neuropsychologia, 1974, 12, 73-81.

Appendix I

Handedness Inventory

A. Are you righthanded or lefthanded?
Right Left Mixed

B. Do you consider yourself to be strongly, moderately, or weakly righthanded or lefthanded?
Strong Moderate Weak

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1. With which hand do you write?
Right Left Mixed
2. With which hand do you use a tennis racquet?
Right Left Mixed
3. With which hand do you use a screwdriver?
Right Left Mixed
4. With which hand do you throw a ball?
Right Left Mixed
5. With which hand do you use a needle in sewing?
Right Left Mixed
6. With which hand do you use a hammer?
Right Left Mixed
7. With which hand do you light a match?
Right Left Mixed
8. With which hand do you use a toothbrush?
Right Left Mixed
9. With which hand do you deal cards?
Right Left Mixed
10. With which hand do you hold a knife when carving meat?
Right Left Mixed

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1. Is your father righthanded or lefthanded? Right Left Mixed Don't Know
2. Is your mother righthanded or lefthanded? Right Left Mixed Don't Know

3. If you have any siblings (brothers or sisters), give the sex, age, and handedness of each (write in more blanks if needed).

   1) Sex___Age___Handedness:
   Right Left Mixed Don't Know
   2) Sex___Age___Handedness:
   Right Left Mixed Don't Know
   3) Sex___Age___Handedness:
   Right Left Mixed Don't Know
   4) Sex___Age___Handedness:
   Right Left Mixed Don't Know
   5) Sex___Age___Handedness:
   Right Left Mixed Don't Know

From Varney, N. R. and Benton, A. L. (1975).

Appendix II

Instructions and Procedures for Subjects and Experimenter in the Witelson Nonesense Shape Formboard Task.

After the subjects are blindfolded the following standardized instructions are read and performed by the experimenter for each subject:

While putting out the board read to the subject the following:

ON THE TABLE IN FRONT OF YOU I AM PLACING A BOARD WHICH IS SITTING ON A STAND SO THAT IT WILL BE UPRIGHT AND NOT TIP OVER. ON THE BOARD ARE SPACES OF VARIOUS SIZES AND SHAPES. ON THE TABLE I AM PUTTING OUT BLOCKS OF VARIOUS SIZES AND SHAPES. THE BLOCKS WILL FIT INTO THE SPACES ON THE BOARD. THERE IS A BLOCK FOR EACH SPACE AND A SPACE FOR EACH BLOCK. WHEN YOU HAVE PLACED A BLOCK IN ITS PROPER SPACE IT WILL FIT IN AND WILL NOT FALL OUT.

After the board and blocks are out say:

THIS IS WHAT THE BOARD FEELS LIKE.

While running the subject's hand (right or left) lightly over the board, say:

HERE IS ONE SIDE, HERE IS THE TOP, AND HERE IS THE OTHER SIDE. THIS IS THE STAND THAT YOU FEEL OUT HERE AT THE SIDE.

Guide the subject's hand to the two sides of the stand.

AS YOU RUN YOUR HAND OVER THE BOARD YOU CAN FEEL THE VARIOUS SPACES.

Run subject's hand quickly and lightly over the entire board.
Then say:

OUT HERE IN FRONT OF YOU ARE ALL THE BLOCKS.

Run subject's hand quickly and lightly over the blocks.
Then say:

HOW, USING ONLY YOUR RIGHT/LEFT HAND I WANT YOU TO FIT THE BLOCKS INTO THEIR PROPER SPACES ON THE BOARD.
DO YOU HAVE ANY QUESTIONS?

Wait for any questions and answer all that you can.[12]

REMEMBER TO DO IT AS QUICKLY AS YOU CAN.
ALL RIGHT - READY? BEGIN.

Experimenter starts timing.
After the subject has finished the task with his right/left hand, and the experimenter records the time to complete the 1st Hand trial, say:

DO NOT REMOVE YOUR BLINDFOLD.
THAT WAS THE LAST BLOCK THAT YOU PUT IN. NOW I WOULD LIKE YOU TO DO THE SAME THING OVER AGAIN. BUT THIS TIME USING ONLY YOUR LEFT/RIGHT HAND.

Quickly show the subject the shape of the board again and remind him that it is the same board and the same blocks; that he is to do the same task again as quickly as possible but using only his left/right hand this time.
After the subject has finished the task with his left/right hand, and the experimenter records the time to complete the 2nd Hand trial, say:

DO NOT REMOVE YOUR BLINDFOLD.
THAT WAS THE LAST BLOCK YOU JUST PUT IN. NOW KEEP THE BLINDFOLD ON BECAUSE I WANT YOU TO DO THIS STILL ANOTHER TIME. THIS TIME YOU WILL BE ABLE TO USE BOTH HANDS. REMEMBER, PUT THE BLOCKS IN THEIR PROPER PLACES AS QUICKLY AS YOU CAN USING BOTH HANDS.
READY? BEGIN.

After the subject has finished the task with both hands, and the experimenter records the time to complete the Both Hands trial, say:

DO NOT REMOVE YOUR BLINDFOLD
THAT WAS THE LAST BLOCK YOU JUST PUT IN.

Place the tack board over the cover of the formboard. The tack board will have a sheet of plain bond paper tacked onto it. Place on the table directly in front of the subject the pad of paper and HB pencil.
Then say:

I HAVE PUT A COVER OVER THE BOARD, IT IS THE SAME SHAPE AND SIZE AS THE OTHER BOARD. THE ONLY DIFFERENCE IS THAT NOW THE BOARD IS SMOOTH AND FLAT AND HAS NO SPACES ON IT. WOULD YOU GIVE ME YOUR RIGHT/LEFT HAND PLEASE.

Take subject's hand and run it over the whole tack board.
Then say:

AS YOU CAN FEEL IT IS SMOOTH AND FLAT.
IN FRONT OF YOU HERE IS A PAD OF PAPER AND A PENCIL.

Place subject's preferred hand on the pad of paper and pencil and then say:

ON EACH SINGLE SHEET OF PAPER I WOULD LIKE YOU TO DRAW ONE OF THE SHAPES THAT WERE ON THE BOARD. AFTER YOU HAVE DRAWN THE SHAPE I WOULD LIKE YOU TO RIP IT OUT OF THE PAD AND THEN SHOW ME WHERE ON THE BOARD YOU THINK THE SHAPE WAS LOCATED. IN ORDER TO BETTER LOCATE WHERE THE SHAPE WAS IT MIGHT HELP IF YOU THOROUGHLY FEEL OUT THE BOARD EACH TIME YOU WANT TO PLACE A DRAWN SHAPE. AFTER YOU HAVE DECIDED WHERE TO PUT THE SHAPE I WILL TACK IT TO THE BOARD. IF YOU SHOULD CHANGE YOUR MIND AS TO A SHAPE LOCATION, AT A LATER TIME, YOU CAN STILL CHANGE IT. IF YOU REMEMBER A CERTAIN SHAPE BUT DO NOT REMEMBER WHERE IT GOES TELL ME AND THEN TRY TO PUT IT IN AS BEST YOU CAN. REMEMBER, DRAW ONLY ONE SHAPE PER PAGE, AND AFTER EACH DRAWING TRY AND LOCATE WHERE IT WAS ON THE BOARD. YOU ARE NOT BEING TIMED FOR THIS PART AND MAY PROCEED AT YOUR OWN PACE.
ARE THERE ANY QUESTIONS?
YOU MAY BEGIN THEN.

After each drawing and the placing of the drawing by the subject, at a location on the tack board, the experimenter will tack the drawing onto the board. The experimenter will take care that when tacking the drawing to the board he keeps the orientation of the drawing the same as the orientation the subject used. When the subject has drawn as many shapes as he can remember the Blindfold Location (BL) and Memory (BM) condition is completed.
Make sure the cover is on the formboard and remove the whole board so that it is not visible to the subject.
Then say:

YOU MAY NOW REMOVE YOUR BLINDFOLD.

Place directly in front of the subject a letter size sheet of plain bond paper and HB pencil.
Then say:

NOW I WANT YOU TO DRAW A PICTURE OF THE BOARD THAT YOU WERE JUST WORKING WITH. MOST PEOPLE FIND IT HELPFUL TO USE THE OUTSIDE EDGES OF THE PAPER AS THE OUTLINE OF THE SHAPE OF THE BOARD AND THEN FILL IN THE SHAPES.

In case the subject may be confused, point out that the outside shape should represent the board, but not the stand.
Then say:

DRAW IN AS MANY OF THE SHAPES AS YOU CAN REMEMBER AND TRY TO PUT THEM IN THEIR PROPER PLACES AS WELL AS YOU CAN REMEMBER. IF YOU REMEMBER A CERTAIN SHAPE BUT DO NOT REMEMBER WHERE IT GOES PUT IT IN AS BEST YOU CAN. THINK CAREFULLY, BUT PUT DOWN ALL OF THE SHAPES YOU CAN REMEMBER, AND ALSO TRY TO PUT

THEM IN THEIR CORRECT LOCATIONS. YOU ARE NOT BEING TIMED FOR THIS PART AND MAY PROCEED AT YOUR OWN PACE.
ARE THERE ANY QUESTIONS?
YOU MAY BEGIN THEN.

When the subject cannot remember any more shapes or their locations, the Visual Location (VL) and Memory (VM) condition, and the test, is completed.

Appendix III

Individual Subject Data

Table 10.

Individual Subject Performances for the Latency Trials and Memory and Location Conditions.

Ss#	Sex	Age	1st Hand	2nd Hand	Both Hands	Total Latency	Blindfold Loc	Blindfold Mem	Visual Loc	Visual Mem
				Preferred Group						
52*	M	20	1148	298	342	1788	7	9	8	10
54*	M	28	1030	687	247	1964	4	8	4	7
56*	M	23	650	367	303	1320	2	6	5	7
58*	M	24	742	1052	295	2089	7	8	7	9
60*	M	25	998	342	200	1540	5	9	4	8
62*	F	30	526	580	397	1403	4	8	4	8
64*	F	27	558	535	532	1625	3	5	4	5
66	F	38	1281	646	409	2336	2	8	0	6
68*	F	18	507	654	147	1308	3	9	4	9
70*	F	20	1163	1284	654	3101	7	7	7	7
72	F	35	774	400	184	1358	0	8	0	7
74	F	43	1063	1340	497	2900	5	7	4	6
78	F	38	699	510	265	1474	6	8	5	9
80	F	38	782	687	435	1904	4	6	6	7
84*	F	21	333	331	244	908	4	7	5	7
86	F	43	437	1522	564	2523	2	5	2	4
88	F	33	1045	460	263	1768	3	9	1	7
90	F	45	539	342	298	1179	2	4	2	3
96*	F	25	730	461	181	1372	5	6	6	6
98*	F	18	871	488	180	1539	5	6	5	6
				Nonpreferred Group						
49*	M	29	1176	880	561	2617	5	7	4	7
51*	M	22	540	622	463	1625	6	8	4	8
53*	M	20	680	924	130	1734	7	8	9	9
55*	M	24	554	657	457	1665	7	8	4	5
57*	M	22	922	401	356	1679	9	9	10	10
59*	M	22	428	347	220	995	7	8	6	8
61*	M	22	339	431	233	1003	7	8	4	6
63	F	32	614	657	350	1621	6	7	2	3
65*	F	20	889	700	203	1792	7	10	6	9
67	F	34	1531	785	244	2560	9	10	9	9
69*	F	24	725	644	315	1684	7	9	6	6
71*	F	28	1215	742	269	2226	6	8	6	8
73	F	35	407	543	273	1223	5	6	3	5
77*	F	20	327	284	436	1047	6	8	5	8
79*	F	26	662	896	353	1911	3	7	3	6
85*	F	25	838	379	237	1454	6	8	6	9
87	F	33	584	292	166	1042	8	9	6	8
95	F	38	249	626	150	1025	0	4	0	1
97*	M	20	780	525	151	1456	8	10	8	9
99*	F	23	455	299	190	944	3	6	1	4

*Subject data used for the Age-Selected (N=27) analyses.

Table 11.

Preferred Group Individual Subject Performance for Locating/Remembering the Shapes in the Blindfold Location (BL) and Memory (BM), and Visual Location (VL) and Memory (VM) Conditions. (1 = a correcty response and 0 = an incorrect response.)

Subject #		52	54	56	58	60	62	64	66	68	70	72	74	78	80	84	86	88	90	96	98	Total
Shape 1	BL	1	1	0	1	1	1	1	1	1	1	0	1	1	0	1	0	0	0	1	1	14
	BM	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	18
	VL	1	1	0	1	1	1	1	0	1	1	0	1	1	1	1	0	0	0	1	1	14
	VM	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	17
Shape 2	BL	1	0	0	1	0	0	0	0	1	1	0	1	0	0	1	0	0	1	0	0	7
	BM	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	0	1	16
	VL	1	1	0	1	0	0	0	0	1	1	0	1	0	0	1	0	0	1	0	0	8
	VM	1	1	0	1	0	0	0	1	1	1	1	1	1	1	1	0	1	1	0	1	14
Shape 3	BL	1	1	0	0	1	1	1	0	1	1	0	0	1	0	0	0	1	0	1	0	10
	BM	1	1	0	0	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1	0	13
	VL	1	1	1	0	1	0	0	0	1	1	0	0	1	0	1	0	1	0	1	0	10
	VM	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	0	1	0	1	0	14
Shape 4	BL	1	0	0	1	0	1	0	0	0	1	0	0	0	0	1	1	0	1	1	0	8
	BM	1	1	0	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	0	15
	VL	1	0	0	1	0	1	0	0	0	1	0	0	1	1	0	1	0	1	1	0	9
	VM	1	1	1	1	1	1	0	0	1	1	1	0	1	1	1	1	1	1	1	0	16
Shape 5	BL	0	0	1	1	1	0	0	1	0	0	0	0	0	1	0	0	1	0	1	1	8
	BM	1	1	1	1	1	0	0	1	1	0	0	1	1	1	0	0	1	0	1	1	13
	VL	0	0	1	1	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	1	7
	VM	1	0	1	1	1	0	0	0	1	0	1	1	1	1	0	0	0	0	1	1	11
Shape 6	BL	1	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	7
	BM	1	1	1	1	1	0	0	0	1	0	1	1	1	1	0	1	0	0	1	1	13
	VL	1	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	7
	VM	1	1	1	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	1	1	10
Shape 7	BL	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3
	BM	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	0	1	0	16
	VL	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	4
	VM	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	0	1	0	16
Shape 8	BL	1	0	0	1	0	1	0	0	0	1	0	1	1	1	0	1	0	0	0	1	9
	BM	1	0	1	1	1	1	0	1	0	1	1	1	1	1	0	1	1	0	0	1	14
	VL	1	0	0	1	0	1	1	0	0	1	0	0	1	1	0	0	0	0	0	1	8
	VM	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	1	15
Shape 9	BL	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	2
	BM	0	0	1	0	0	1	0	1	1	1	0	0	0	0	1	0	1	1	0	0	8
	VL	1	1	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	5
	VM	1	1	0	0	0	1	0	1	1	1	0	0	0	0	1	0	1	0	0	0	8
Shape 10	BL	1	0	1	1	1	0	1	0	0	1	0	1	1	1	1	0	0	0	0	1	11
	BM	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	0	1	17
	VL	1	0	1	1	1	0	1	0	0	1	0	1	1	1	1	1	0	0	0	1	12
	VM	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	17
TOTAL		34	23	20	31	26	24	17	16	25	28	15	22	28	23	23	13	20	11	23	22	444

Table 12.

Nonpreferred Group Individual Subject Performance for Locating/Remembering the Shapes in the Blindfold Location (BL) and Memory (BM), and Visual Location (VL) and Memory (VM) Conditions. (1 = a correct response and 0 = an incorrect response.)

Subject #		49	51	53	55	57	59	61	63	65	67	69	71	73	77	79	85	87	95	97	99	Total
Shape 1	BL	1	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	0	1	1	16
	BM	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	19
	VL	1	0	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	0	1	1	16
	VM	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	0	1	1	17
Shape 2	BL	0	1	0	1	1	1	0	1	1	1	0	1	1	0	1	0	1	0	1	0	12
	BM	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	0	1	0	1	0	15
	VL	0	1	1	0	1	1	0	1	1	0	0	1	0	0	1	0	1	0	1	0	10
	VM	1	1	1	1	1	1	1	1	1	0	0	1	0	0	1	1	1	0	1	0	14
Shape 3	BL	0	0	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	1	0	14
	BM	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	0	15
	VL	0	0	1	1	1	0	0	0	0	1	1	0	0	1	1	1	1	0	1	0	10
	VM	0	0	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	1	0	13
Shape 4	BL	1	0	0	1	1	0	1	0	1	1	1	1	1	0	0	1	1	0	1	0	12
	BM	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	18
	VL	1	0	1	1	1	0	0	0	1	1	1	1	1	0	0	1	1	0	1	0	12
	VM	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	0	17
Shape 5	BL	1	1	1	1	1	1	0	1	1	1	0	0	0	0	0	1	1	0	0	0	11
	BM	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	0	1	0	15
	VL	1	1	1	0	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	7
	VM	1	1	1	0	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	0	10
Shape 6	BL	0	1	0	1	1	1	1	1	1	0	1	0	0	0	1	1	1	0	0	1	12
	BM	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	17
	VL	0	0	0	0	1	1	0	0	0	1	1	0	0	0	0	1	0	0	0	0	5
	VM	1	1	0	0	1	1	0	0	1	1	1	0	1	1	0	1	1	0	1	0	12
Shape 7	BL	1	1	1	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	1	0	7
	BM	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	17
	VL	0	0	1	0	1	0	1	0	1	1	0	0	0	1	0	0	0	0	1	0	7
	VM	1	1	1	0	1	0	1	0	1	1	0	1	1	1	1	1	1	0	1	1	15
Shape 8	BL	0	0	1	0	1	0	1	1	1	1	1	1	1	1	0	1	0	0	1	0	12
	BM	0	0	1	0	1	0	1	1	1	1	1	1	1	1	0	1	0	1	1	1	14
	VL	0	0	1	0	1	0	1	1	0	1	1	1	1	1	0	1	0	0	1	0	11
	VM	0	0	1	0	1	0	1	1	1	1	1	1	1	1	0	1	0	0	1	1	13
Shape 9	BL	1	1	1	1	1	1	0	0	0	1	1	1	0	1	0	0	1	0	1	0	12
	BM	1	1	1	1	1	1	0	0	1	1	1	1	0	1	0	1	1	0	1	0	14
	VL	1	1	1	1	1	1	0	0	1	1	1	1	0	0	0	0	1	0	1	0	12
	VM	1	1	1	1	1	1	0	0	1	1	1	1	0	0	0	1	1	0	1	0	13
Shape 10	BL	0	1	1	0	1	1	1	0	0	1	1	1	1	1	0	0	1	0	1	1	13
	BM	0	1	1	0	1	1	1	0	1	1	1	1	1	1	0	0	1	0	1	1	14
	VL	0	1	1	0	1	1	1	0	1	1	0	1	1	1	0	0	1	0	1	0	12
	VM	0	1	1	0	1	1	1	0	1	1	0	1	1	1	0	0	1	0	1	1	13
Total		23	26	33	24	38	28	24	18	32	37	28	28	19	27	19	29	31	5	35	14	518

Appendix IV

Statistical Analyses

Table 13.

Correlated T-Tests for the Preferred Group (d.f.=18).

T-test Values

Variable	1st Hand	2nd Hand	Both Hands	BL	VL	BM	VM
1st Hand	0						
2nd Hand	1.268	0					
Both Hands	2.893	6.154	0				
BL	315.914	408.274	160.024	0			
VL	257.156	345.355	137.246	1.166	0		
BM	428.169	521.036	218.576	1.110	1.740	0	
VM	342.989	458.207	188.031	0.568	1.295	1.026	0

Probabilities of T-test Values

Variable	1st Hand	2nd Hand	Both Hands	BL	VL	BM	VM
1st Hand	1.000						
2nd Hand	0.221	1.000					
Both Hands	0.010	0.000	1.000				
BL	0.000	0.000	0.000	1.000			
VL	0.000	0.000	0.000	0.259	1.000		
BM	0.000	0.000	0.000	0.282	0.099	1.000	
VM	0.000	0.000	0.000	0.577	0.212	0.318	1.000

Table 14.

Correlated T-Tests for the Nonpreferred Group (d.f.=18).

T-test Values

Variable	1st Hand	2nd Hand	Both Hands	BL	VL	BM	VM
1st Hand	0						
2nd Hand	2.328	0					
Both Hands	5.049	2.454	0				
BL	361.006	205.709	118.971	0			
VL	319.565	165.646	97.583	1.649	0		
BM	552.002	295.962	172.689	3.606	4.541	0	
VM	347.085	186.137	108.385	0.598	1.069	3.473	0

Probabilities of T-test Values

Variable	1st Hand	2nd Hand	Both Hands	BL	VL	BM	VM
1st Hand	1.000						
2nd Hand	0.032	1.000					
Both Hands	0.000	0.025	1.000				
BL	0.000	0.000	0.000	1.000			
VL	0.000	0.000	0.000	0.117	1.000		
BM	0.000	0.000	0.000	0.002	0.000	1.000	
VM	0.000	0.000	0.000	0.557	0.299	0.003	1.000

Table 15

Pearson Correlation Coefficients

Variable #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1.000																	
2	-0.160	1.000																
3	0.243	-0.428	1.000															
4	0.165	0.055	0.069	1.000														
5	0.117	-0.086	0.270	0.255	1.000													
6	0.168	-0.029	0.207	0.158	0.526	1.000												
7	-0.467	0.365	-0.443	0.263	0.004	-0.020	1.000											
8	-0.250	0.291	-0.414	0.423	-0.133	-0.253	0.630	1.000										
9	-0.195	0.370	-0.497	0.300	0.032	-0.064	0.817	0.478	1.000									
10	-0.000	0.353	-0.476	0.403	-0.119	-0.153	0.582	0.780	0.717	1.000								
11	-0.076	0.061	-0.281	-0.117	-0.036	-0.099	0.126	-0.082	0.213	-0.019	1.C00							
12	-0.032	-0.024	-0.148	-0.126	-0.115	-0.025	0.093	-0.136	0.094	-0.090	0.743	1.000						
13	0.072	-0.151	-0.090	-0.232	-0.132	-0.051	-0.037	-0.076	-0.056	-0.133	-0.C82	-0.078	1.000					
14	-0.160	-0.111	-0.059	-0.050	-0.131	-0.089	0.068	0.051	0.090	0.167	-0.061	0.010	-0.035	1.000				
15	-0.055	-0.190	-0.108	-0.141	-0.189	-0.099	0.018	-0.023	0.020	0.014	-0.103	-0.052	0.731	0.656	1.000			
16	0.100	0.218	-0.142	0.157	-0.164	0.035	-0.107	0.217	-0.033	0.207	-0.065	-0.094	-0.106	-0.214	-0.226	1.000		
17	0.182	0.210	-0.154	0.028	0.099	0.022	0.029	0.079	0.120	0.088	0.121	0.161	-0.066	-0.349	-0.288	0.525	1.000	
18	-0.260	0.392	-0.526	0.397	-0.044	-0.120	0.886	0.791	0.902	0.876	0.082	0.000	-0.083	0.111	0.013	0.065	0.094	1.000

Variable Name

1. Groups
2. Sex
3. Age
4. 1st Hand
5. 2nd Hand
6. Both Hands
7. Blindfold Location
8. Blindfold Memory
9. Visual Location
10. Visual Memory
11. Handedness
12. Hand Preferences
13. Father's Handedness
14. Mother's Handedness
15. Total Parental Handedness
16. Sibling Total Handedness
17. Sibling Average Handedness
18. Total Shapes Located and Remembered

Table 16.

T-Tests for Independent Means between Males and Females of the Preferred and Nonpreferred Groups (N=27).

Variable		Males Mean	Males S.D.	Females Mean	Females S.D.	d.f.	T	P One-tail	P Two-tail
Preferred									
Age		24.00	2.92	22.71	4.68	10	0.54	0.30	0.60
1st Hand		913.60	208.89	669.71	277.03	10	1.65	0.06	0.13
2nd Hand		549.20	320.56	619.00	310.13	10	0.38	0.36	0.71
Both Hands		277.40	54.89	333.57	198.23	10	0.61	0.28	0.56
Total Latency		1740.20	312.52	1608.00	696.64	10	0.39	0.35	0.70
Blindfold	Location	5.00	2.12	4.43	1.40	10	0.57	0.29	0.58
	Memory	8.00	1.22	6.86	1.35	10	1.50	0.08	0.16
Visual	Location	5.60	1.82	5.00	1.15	10	0.70	0.25	0.50
	Memory	8.20	1.30	6.86	1.35	10	1.73	0.06	0.12
Nonpreferred									
Age		22.63	2.88	23.71	2.98	13	0.72	0.24	0.48
1st Hand		677.38	275.11	730.14	292.93	13	0.36	0.36	0.72
2nd Hand		598.38	215.43	563.43	241.40	13	0.30	0.39	0.77
Both Hands		321.38	160.72	286.14	88.15	13	0.52	0.31	0.62
Total Latency		1596.75	508.00	1579.71	463.16	13	0.07	0.47	0.95
Blindfold	Location	7.00	1.20	5.43	1.72	13	2.08	0.03	0.06
	Memory	8.25	0.89	8.00	1.29	13	0.44	0.33	0.67
Visual	Location	6.13	2.53	4.71	1.98	13	1.19	0.13	0.26
	Memory	7.75	1.67	7.14	1.86	13	0.67	0.26	0.52

Table 17.

Correlated T-Tests for the Age-Selected Preferred Group (d.f.=10).

T-test Values

Variable	1st Hand	2nd Hand	Both Hands	BL	VL	BM	VM
1st Hand	0						
2nd Hand	0.354	0					
Both Hands	1.963	2.737	0				
BL	336.739	321.937	149.009	0			
VL	344.329	352.852	176.603	0.857	0		
BM	325.929	348.421	183.814	0.666	0.117	0	
VM	303.571	331.152	170.647	0.505	0.051	0.356	0

Probabilities of T-test Values

Variable	1st Hand	2nd Hand	Both Hands	BL	VL	BM	VM
1st Hand	1.000						
2nd Hand	0.730	1.000					
Both Hands	0.078	0.021	1.000				
BL	0.000	0.000	0.000	1.000			
VL	0.000	0.000	0.000	0.412	1.000		
BM	0.000	0.000	0.000	0.521	0.909	1.000	
VM	0.000	0.000	0.000	0.625	0.961	0.729	1.000

Table 18.

Correlated T-Tests for the Age-Selected Nonpreferred Group (d.f.=13).

T-test Values

Variable	1st Hand	2nd Hand	Both Hands	BL	VL	BM	VM
1st Hand	0						
2nd Hand	0.936	0					
Both Hands	3.018	2.062	0				
BL	306.130	247.931	144.855	0			
VL	226.823	171.009	105.086	2.286	0		
BM	476.903	374.563	227.691	2.688	4.371	0	
VM	310.194	229.953	137.173	0.279	1.961	2.348	0

Probabilities of T-test Values

Variable	1st Hand	2nd Hand	Both Hands	BL	VL	BM	VM
1st Hand	1.000						
2nd Hand	0.366	1.000					
Both Hands	0.010	0.060	1.000				
BL	0.000	0.000	0.000	1.000			
VL	0.000	0.000	0.000	0.040	1.000		
BM	0.000	0.000	0.000	0.019	0.001	1.000	
VM	0.000	0.000	0.000	0.784	0.072	0.035	1.000

Table 19.

Duncan's Multiple Range Test for Differences between the Ten Shape Means Located/Remembered Correctly (alpha=0.01).

Shape	Means	9	5	6	7	8	2	3	4	10	1	Shortest Significant Ranges
		.462	.512	.513	.519	.600	.600	.619	.669	.681	.891	
9	.462		.050	.051	.057	.138	.138	.157	.207	.219	.357	R2=3.6450
5	.512			.001	.007	.088	.088	.107	.157	.169	.307	R3=3.7989
6	.513				.006	.087	.087	.106	.156	.168	.306	R4=3.9011
7	.519					.081	.081	.100	.150	.162	.300	R5=3.9748
8	.600						.000	.019	.069	.081	.219	R6=4.0406
2	.600							.019	.069	.081	.219	R7=4.0964
3	.619								.050	.062	.200	R8=4.1432
4	.669									.012	.150	R9=4.1827
10	.681										.138	R10=4.2164

9 5 6 7 8 2 3 4 10 1

Any two means not underscored by the same line are significantly different.

Any two treatment means underscored by the same line are not significantly different.

Table 20

Duncan's Multiple Range Test for Differences Between the Twenty Means of the Preferred (P) and Nonpreferred (N) Groups for Each of the Ten Shapes Located/Remembered Correctly (alpha=0.01)

	Shape	P9	P6	P7	P5	N5	P2	N7	N6	P8	P3	P4	N8	N9	N2	N10	N3	P10	N4	P1	N1	Shortest Significant Ranges
	Means	.287	.462	.487	.487	.537	.563	.575	.575	.575	.587	.600	.625	.637	.637	.650	.650	.712	.737	.787	.850	R2=3.6451
P9	.287		.175	.200	.200	.250	.276	.288	.288	.288	.300	.313	.338	.350	.350	.363	.363	.425	.450	.500	.563	R3=3.7989
P6	.462			.025	.025	.075	.101	.113	.113	.113	.125	.138	.163	.175	.175	.188	.188	.250	.275	.325	.388	R4=3.9011
P7	.487				.000	.050	.076	.088	.088	.088	.100	.113	.138	.150	.150	.163	.163	.225	.250	.300	.363	R5=3.9749
P5	.487					.050	.075	.088	.088	.088	.100	.113	.138	.150	.150	.163	.163	.225	.250	.300	.363	R6=4.0407
N5	.537						.026	.038	.038	.038	.050	.063	.088	.100	.100	.113	.113	.175	.200	.250	.313	R7=4.0964
P2	.563							.012	.012	.012	.024	.037	.062	.074	.074	.087	.087	.149	.174	.224	.287	R8=4.1432
N7	.575								.000	.000	.012	.025	.050	.062	.062	.075	.075	.137	.162	.212	.275	R9=4.1828
N6	.575									.000	.012	.025	.050	.062	.062	.075	.075	.137	.162	.212	.275	R10=4.2164
P8	.575										.012	.025	.050	.062	.062	.075	.075	.137	.162	.212	.275	R11=4.2453
P3	.587											.013	.038	.050	.050	.063	.063	.125	.150	.200	.263	R12=4.2703
P4	.600												.025	.037	.037	.050	.050	.112	.137	.187	.250	R13=4.2922
N8	.625													.012	.012	.025	.025	.087	.112	.162	.225	R14=4.3115
N9	.637														.000	.013	.013	.075	.100	.150	.213	R15=4.3388
N2	.637															.013	.013	.075	.100	.150	.213	R16=4.3520
N10	.650																.000	.062	.087	.137	.200	R17=4.3657
N3	.650																	.062	.087	.137	.200	R18=4.3795
P10	.712																		.025	.075	.138	R19=4.3933
N4	.737																			.050	.113	R20=4.4068
P1	.787																				.063	
N1	.850																					

P9 P6 P7 P5 N5 P2 N7 N6 P8 P3 P4 N8 N9 N2 N10 N3 P10 N4 P1 N1

Any two means not underscored by the same line are significantly different.

Any two means underscored by the same line are not significantly different.